1982

An econometric analysis of world wheat trade: a trade flow approach

Masayoshi Honma

Iowa State University

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AN ECONOMETRIC ANALYSIS OF WORLD WHEAT TRADE: A TRADE FLOW APPROACH

Iowa State University

Ph.D. 1982

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by

Masayoshi Honma

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In Charge of Major Work

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For the Major Department

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For the Graduate College

Iowa State University
Ames, Iowa
1982
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CHAPTER I. INTRODUCTION

The linkage of world food economies has been strengthened and global food interdependence is growing. International trade of agricultural commodities and its impacts on exporters and importers are the most important aspects of the food interdependence in the world. Since the 1950s, world trade of agricultural commodities has grown rapidly with expanding trade liberalization. This growth, however, has been accompanied by structural changes in the world food system. During the 1950s and 1960s, a relatively secure food system was maintained by the United States, which provided a series of government programs for concessional exports and food aid. This government assistance for exports led to increases in the level of food dependence, especially in less developed countries, which definitely increased their imports of food. However, the world food economies entered a new era in the 1970s. The concurrent devaluation of the U.S. dollar and the Soviet Union's grain purchases between 1972-73 were followed by a great expansion of world agricultural trade and sharp increases in food prices. The expansion of world grain trade in the 1970s was sustained by the entrance of centrally planned economies in the world grain market as major importers and the increases in grain imports of less developed countries based on commercial trade. Indeed, U.S. grain exports by concessional sales have declined to a small amount, while the commercial exports to less developed countries have shown very rapid increases. On the other hand, the emergence of centrally planned economies in the world grain market became a significant factor in
destabilizing the market because of their erratic market behavior. In addition to these movements, more recently, the United States implemented a grain embargo against Russia in 1980, in response to the latter's invasion of Afghanistan. The embargo influenced the world market through changing trade flows of world grains. This demonstrated the importance of government behavior in international trade and the world food system.

In the international movements of the world food system, wheat has been at the center of issues because of its importance. Wheat is the staple food in the diet of over one-half of the world population and it provides about one-fifth of all calories consumed by humans. Wheat occupies about one-fourth of the world cropland and accounts for nearly 30 percent of the world grain production. Wheat is the largest single commodity among all agricultural commodities traded in the world and accounts for 40 to 50 percent of the world grain trade. Basic data on the trends of world production and trade for wheat in comparison with total grains are presented in Table 1.1.

Objectives

The general purpose of this study is to analyze the structure and mechanism of world wheat trade focusing on the networks of international trade flows of wheat. The increasing interdependence of agricultural economies in the world requires studies which explain market behavior in an international setting. For this reason, the study develops an econometric model of world wheat trade, which contributes to understanding the world market structure and the nature of global interdependence of the world's wheat economies. The study centers on
Table 1.1. World grain area harvested, production and trade, 1961-1979<sup>a</sup>

<table>
<thead>
<tr>
<th>Year</th>
<th>Area harvested (million hectares)</th>
<th>Production (million MT&lt;sup&gt;b&lt;/sup&gt;)</th>
<th>Trade (exports) (million MT)</th>
<th>Trade as % of production</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Grains total</td>
<td>Wheat</td>
<td>Grains total</td>
<td>Wheat</td>
</tr>
<tr>
<td>1961</td>
<td>665.0</td>
<td>203.2</td>
<td>923.9</td>
<td>228.5</td>
</tr>
<tr>
<td>1962</td>
<td>669.4</td>
<td>207.8</td>
<td>981.9</td>
<td>259.0</td>
</tr>
<tr>
<td>1963</td>
<td>675.1</td>
<td>207.3</td>
<td>979.7</td>
<td>239.6</td>
</tr>
<tr>
<td>1964</td>
<td>686.3</td>
<td>217.1</td>
<td>1030.0</td>
<td>277.1</td>
</tr>
<tr>
<td>1965</td>
<td>686.1</td>
<td>219.0</td>
<td>1025.8</td>
<td>267.4</td>
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<td>1966</td>
<td>687.4</td>
<td>218.2</td>
<td>1093.7</td>
<td>310.1</td>
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<td>1967</td>
<td>700.9</td>
<td>222.0</td>
<td>1141.8</td>
<td>298.9</td>
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<td>331.2</td>
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<td>707.5</td>
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<td>215.1</td>
<td>1278.7</td>
<td>346.8</td>
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<td>1973</td>
<td>723.0</td>
<td>221.4</td>
<td>1377.1</td>
<td>376.7</td>
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<td>727.0</td>
<td>222.8</td>
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<td>1975</td>
<td>734.0</td>
<td>228.9</td>
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<td>1976</td>
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<td>756.7</td>
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<td>238.7</td>
<td>1553.1</td>
<td>425.5</td>
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</tr>
</tbody>
</table>

^aSources: FAO [24, 25].

^bMetric tons.

^cExcluding wheat flour.
trade flows of wheat connecting exporting countries with importing countries, in order to emphasize the clarification of the international trade linkages.

The more specific objectives of this study are:

(1) To review and evaluate past studies of the world trade models of agricultural commodities.

(2) To give a theoretical background and validity for analyzing trade flows.

(3) To specify and estimate trade flow equations of wheat in the framework of the model for product differentiation by place of production.

(4) To specify and estimate total import demand equations for wheat in each importing market region.

(5) To specify and estimate supply side equations of wheat exports, including production, inventories, and domestic demand equations for each exporting country.

(6) To incorporate all the equations into a complete system of world wheat trade model.

(7) To evaluate the econometric model of world wheat trade by simulation.

(8) To analyze the impacts of selected exogenous factors on the world wheat trade.

Exporter and Importer Regional Breakdown

World wheat trade is characterized by a handful of exporters and a greater number of importers. Major exporting countries are the
United States, Canada, Australia, Argentina, and France. Actual gross exports and percentage market shares for these major wheat-exporting countries are shown in Table 1.2. The United States is consistently the largest wheat exporter and accounts for about 40 percent, on the average, of world wheat exports. Canada supplied about one-fourth of the world's wheat exports until the middle 1960s, but its share declined during the 1970s. Australia's share fluctuates between 10 and 15 percent of the market. Argentina's share is the most unstable in the range of 2 to 13 percent. France's market share increased rapidly in the late 1960s and French exports now account for 10 percent of the market. It is noted that French exports include exports to other members of the European Economic Community (EEC). These major five exporters account for over 85 percent, on the average, of gross world exports of wheat. In this study, discussions on the supply side of wheat exports are limited to these five major exporting countries because of the lack of adequate data on trade flows and prices for other minor exporters.

The selection of importing countries in dividing the world into subregions has several alternatives. Geographical division is most often used in groupings of countries. However, geographical groupings of countries are not adequate in this study because they do not represent similarities in market behavior in world trade. Especially, care should be taken in grouping less developed countries, which have a variety of income levels. For example, Asia includes middle income oil-producing or newly industrializing countries as well as a number of low-income countries. The demand structure of the former group for imports is different from that of the latter group because of differences in income
Table 1.2. Wheat exports and market shares, 1961-1980

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<th>Year</th>
<th>U.S. Exports (MMT)</th>
<th>Share (%)</th>
<th>Canada Exports (MMT)</th>
<th>Share (%)</th>
<th>Australia Exports (MMT)</th>
<th>Share (%)</th>
<th>Argentina Exports (MMT)</th>
<th>Share (%)</th>
<th>France Exports (MMT)</th>
<th>Share (%)</th>
<th>Total of five Exports (MMT)</th>
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<td>44</td>
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<td>11</td>
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<td>3</td>
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<td>2.8</td>
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<td>25</td>
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<td>4</td>
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<td>6</td>
<td>36.7</td>
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<td>5</td>
<td>9.9</td>
<td>11</td>
<td>81.9</td>
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</table>

^Source: FAO [25].

^Excluding wheat flour.

^Total of the five exporting countries.

^Million metric tons.
level and availability of foreign exchange. In this study, importing countries are divided into ten market regions. The principal criterion used in the breakdown is the degree of similarity in response to price changes; therefore, it is not necessarily consistent with geographical groupings. This criterion in groupings is the same one used by Schmitz et al. [85].

The first breakdown of importing markets adopts a tripartite division of developed countries (referred to as DCs), less developed countries (LDCs), and centrally planned economies (CPs). Moreover, each class is subdivided into three or four regions. The DCs consists of the six original EEC countries (EC-6), the three new EEC countries (EC-3), Japan, and the rest of the developed countries. The LDCs are subdivided into the members of the Organization of Petroleum Exporting Countries (OPEC), the newly industrializing countries (NICs), and the rest of the LDCs. The first two regions are identified as middle income LDCs. Finally, the CPs are divided into the USSR, China, and Eastern Europe. Other CPs are included in the category of the rest of the LDCs because their import demand characteristics are similar to those of the rest of the LDCs. A detailed breakdown of the world for wheat trade is presented in Table 1.3.

Changes in Trade Flows

This study centers around the analysis of trade flows. In order to provide a background for the following discussions, data of wheat trade flows in selected years of 1966-68 and 1976-78 on the average, respectively, are represented in Table 1.4. The figures show actual wheat origin-destination flows of any pairs between the five exporting
Table 1.3. Classification of wheat exporters and importers

<table>
<thead>
<tr>
<th>Region name</th>
<th>Countries included</th>
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<tbody>
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<td><strong>Exporting regions</strong></td>
<td>Argentina, Australia, Canada, France U.S.</td>
</tr>
<tr>
<td><strong>Importing regions</strong></td>
<td></td>
</tr>
<tr>
<td>Developed countries (DCs)</td>
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</tr>
<tr>
<td>EC-6</td>
<td>Belgium and Luxembourg, France, Italy, Netherlands, West Germany</td>
</tr>
<tr>
<td>EC-3</td>
<td>Denmark, Ireland, United Kingdom</td>
</tr>
<tr>
<td>Japan</td>
<td>Japan</td>
</tr>
<tr>
<td>Rest of DCs</td>
<td>Austria, Finland, Greece, Iceland, Malta, Norway, Portugal, Spain, Sweden, Switzerland, Yugoslavia, Israel, South Africa, New Zealand</td>
</tr>
<tr>
<td>Less developed countries (LDCs)</td>
<td></td>
</tr>
<tr>
<td>NICs</td>
<td>Brazil, Hong Kong, Mexico, Singapore, South Korea, Taiwan</td>
</tr>
<tr>
<td>OPEC</td>
<td>Algeria, Equador, Gabon, Indonesia, Iraq, Iran, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates, Venezuela</td>
</tr>
<tr>
<td>Rest of LDCs</td>
<td>Costa Rica, Cuba, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Nicaragua, Panama, Trinidad and Tobago, Bolivia, Chile, Colombia, Paraguay, Peru, Uruguay, Guyana, Ethiopia, Morocco, Sudan, Tunisia, Egypt, Somali Republic, Angola, Camaroon, Dahomey, Ghana, Guinea, Ivory Coast, Kenya, Malawi, Malagasy Republic, Mozambique, Niger, Rhodesia, Rwanda, Senegal, Tanzania, Upper Volta, Uganda, Zaire, Zambia, Cyprus, Jordan, Lebanon, Syria, Turkey</td>
</tr>
</tbody>
</table>
Table 1.3. (Continued)

<table>
<thead>
<tr>
<th>Region name</th>
<th>Countries included</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest of LDCs (continued)</td>
<td>South Yemen, Afghanistan, India, Bangladesh, Nepal, Pakistan, Burma, Sri Lanka, Cambodia, Malaysia, Vietnam, Philippines, North Korea, Outer Mongolia, Thailand</td>
</tr>
<tr>
<td>Centrally planned economies (CPs)</td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>China</td>
</tr>
<tr>
<td>Eastern Europe</td>
<td>Albania, Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, Romania</td>
</tr>
<tr>
<td>USSR</td>
<td>USSR</td>
</tr>
</tbody>
</table>
Table 1.4. Wheat trade flows in the world, 1966-68 average and 1976-78 average^c^b

<table>
<thead>
<tr>
<th>Destination</th>
<th>United States</th>
<th>Canada</th>
<th>Australia</th>
<th>Argentina</th>
<th>France</th>
<th>Total from five exporters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Commercial</td>
<td>PL 480</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1966-68 average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EC-6</td>
<td>1490 (3.5)</td>
<td>0</td>
<td>1488 (3.5)</td>
<td>167 (0.4)</td>
<td>556 (1.3)</td>
<td>826 (2.0)</td>
</tr>
<tr>
<td>EC-3</td>
<td>509 (1.2)</td>
<td>0</td>
<td>1616 (3.8)</td>
<td>527 (1.3)</td>
<td>135 (0.3)</td>
<td>271 (0.6)</td>
</tr>
<tr>
<td>Japan</td>
<td>2137 (5.1)</td>
<td>0</td>
<td>1379 (3.3)</td>
<td>548 (1.3)</td>
<td>1 (0.0)</td>
<td>6 (0.0)</td>
</tr>
<tr>
<td>Rest of DCs</td>
<td>1479 (3.5)</td>
<td>484 (1.1)</td>
<td>287 (0.7)</td>
<td>259 (0.7)</td>
<td>45 (0.1)</td>
<td>239 (0.6)</td>
</tr>
<tr>
<td>NICs</td>
<td>1377 (3.3)</td>
<td>965 (2.3)</td>
<td>102 (0.2)</td>
<td>410 (1.0)</td>
<td>948 (2.3)</td>
<td>55 (0.1)</td>
</tr>
<tr>
<td>OPEC</td>
<td>1092 (2.6)</td>
<td>92 (0.2)</td>
<td>191 (0.5)</td>
<td>300 (0.7)</td>
<td>21 (0.0)</td>
<td>159 (0.4)</td>
</tr>
<tr>
<td>Rest of LDCs</td>
<td>2241 (5.3)</td>
<td>6773 (16.1)</td>
<td>1200 (2.8)</td>
<td>1493 (3.5)</td>
<td>511 (1.2)</td>
<td>799 (1.9)</td>
</tr>
<tr>
<td>China</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1998 (4.7)</td>
<td>1991 (4.7)</td>
<td>521 (1.2)</td>
<td>243 (0.6)</td>
</tr>
<tr>
<td>Eastern Europe</td>
<td>53 (0.1)</td>
<td>0 (0)</td>
<td>548 (1.3)</td>
<td>4 (0.0)</td>
<td>34 (0.1)</td>
<td>767 (1.8)</td>
</tr>
<tr>
<td>USSR</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>2299 (5.5)</td>
<td>42 (0.1)</td>
<td>398 (0.9)</td>
<td>60 (0.1)</td>
</tr>
<tr>
<td>Total exports</td>
<td>10379 (24.6)</td>
<td>8314 (19.7)</td>
<td>11107 (26.4)</td>
<td>5742 (13.6)</td>
<td>3172 (7.5)</td>
<td>3426 (8.1)</td>
</tr>
<tr>
<td></td>
<td>1976-78 average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>-----------------</td>
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<td>-------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td></td>
<td>1642</td>
<td>0</td>
<td>1086</td>
<td>71</td>
<td>410</td>
<td>3408</td>
</tr>
<tr>
<td></td>
<td>(2.9)</td>
<td>(0)</td>
<td>(1.9)</td>
<td>(0.1)</td>
<td>(0.7)</td>
<td>(5.9)</td>
</tr>
<tr>
<td></td>
<td>104</td>
<td>0</td>
<td>1378</td>
<td>24</td>
<td>4</td>
<td>1457</td>
</tr>
<tr>
<td></td>
<td>(0.2)</td>
<td>(0)</td>
<td>(2.4)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(2.5)</td>
</tr>
<tr>
<td>Japan</td>
<td>3246</td>
<td>0</td>
<td>1342</td>
<td>1054</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(5.6)</td>
<td>(0)</td>
<td>(2.3)</td>
<td>(1.8)</td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>Rest of DCs</td>
<td>1027</td>
<td>70</td>
<td>236</td>
<td>12</td>
<td>84</td>
<td>129</td>
</tr>
<tr>
<td></td>
<td>(1.8)</td>
<td>(0.1)</td>
<td>(0.4)</td>
<td>(0.0)</td>
<td>(0.1)</td>
<td>(0.2)</td>
</tr>
<tr>
<td>NICs</td>
<td>4034</td>
<td>412</td>
<td>1110</td>
<td>207</td>
<td>581</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>(7.0)</td>
<td>(0.7)</td>
<td>(1.9)</td>
<td>(0.4)</td>
<td>(1.0)</td>
<td>(0.0)</td>
</tr>
<tr>
<td>OPEC</td>
<td>3706</td>
<td>172</td>
<td>587</td>
<td>1245</td>
<td>260</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>(6.4)</td>
<td>(0.3)</td>
<td>(1.0)</td>
<td>(2.2)</td>
<td>(0.5)</td>
<td>(0.1)</td>
</tr>
<tr>
<td>Rest of LDCs</td>
<td>5881</td>
<td>2078</td>
<td>2004</td>
<td>2814</td>
<td>829</td>
<td>1321</td>
</tr>
<tr>
<td></td>
<td>(10.2)</td>
<td>(3.6)</td>
<td>(3.5)</td>
<td>(4.9)</td>
<td>(1.4)</td>
<td>(2.3)</td>
</tr>
<tr>
<td>China</td>
<td>616</td>
<td>0</td>
<td>2421</td>
<td>2118</td>
<td>279</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(1.1)</td>
<td>(0)</td>
<td>(4.2)</td>
<td>(3.7)</td>
<td>(0.5)</td>
<td>(0)</td>
</tr>
<tr>
<td>Eastern Europe</td>
<td>936</td>
<td>0</td>
<td>864</td>
<td>7</td>
<td>336</td>
<td>180</td>
</tr>
<tr>
<td></td>
<td>(1.6)</td>
<td>(0)</td>
<td>(1.5)</td>
<td>(0.0)</td>
<td>(0.6)</td>
<td>(0.3)</td>
</tr>
<tr>
<td>USSR</td>
<td>2500</td>
<td>0</td>
<td>1987</td>
<td>518</td>
<td>683</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(4.3)</td>
<td>(0)</td>
<td>(3.5)</td>
<td>(0.9)</td>
<td>(1.2)</td>
<td>(0)</td>
</tr>
<tr>
<td>Total exports</td>
<td>23691</td>
<td>2732</td>
<td>13015</td>
<td>8071</td>
<td>3465</td>
<td>6584</td>
</tr>
<tr>
<td></td>
<td>(41.2)</td>
<td>(4.7)</td>
<td>(22.6)</td>
<td>(14.0)</td>
<td>(6.0)</td>
<td>(11.4)</td>
</tr>
</tbody>
</table>

*aSource: UN [103] and USDA [107, 110, 111].

*bExcluding wheat flour.

*cFigures in parentheses represent percent shares in the total exports by the five countries.
countries and the ten market regions. The figures in parentheses represent percent shares of each trade flow in the total exports by the five countries; therefore, the figures show the relative importance of each trade flow in the world trade. The term "world trade", hereafter, refers to trade conducted only by the five major countries and the ten importing regions. It is noted that exports by the U.S. are divided into two parts; exports by commercial sales and exports by Public Law 480 (PL 480) programs, under which most of the concessional exports and food aid are managed.

Comparison of the trade flows between the two periods, 1966-68 and 1976-78, reveals structural changes in world wheat trade during the decade. For the period of 1966-68, the most important trade flow was the PL 480 shipments by the U.S. to the rest of the LDCs, accounting for 16 percent of the total exports by the five exporters. The total PL 480 shipments by the U.S. accounted for about 20 percent of the world trade. Other trade flows, which showed relatively high significance in world trade, were exports by the U.S. to Japan and to the rest of the LDCs on a commercial basis, exports by Canada to China and to the USSR, and exports by Australia to China, each of which accounts for about 5 percent of the world trade. As total imports of wheat, the rest of the LDCs had an import share of more than 30 percent, followed by China, the EEC-6, Japan, and the NICs, each of which accounted for about 10 percent of the world trade. For the period of 1976-78, several significant changes are observed. The most significant change during the decade was a great decline in the role of PL 480 shipments in world trade. Instead,
the most important trade flow was shifted to commercial exports by the U.S. to the rest of the LDCs, followed by commercial exports by the U.S. to the NICs and to OPEC, which show increasing importance in world trade. Other flows which significantly increased trade shares were exports by the U.S. to the USSR, exports by France to EC-6, and exports by Australia to the rest of the LDCs. The shifts in importance of each importing region are observed in increases in the total import share of the NICs, OPEC and the USSR, and in declines in the share of EC-3 and the rest of the DCs.

In the following discussions, the study is concerned with only commercial exports and imports of wheat, because the shipments of wheat by PL 480 are outside the market mechanism of world trade. Therefore, the shipments by PL 480 are treated exogenously in the system of the world wheat trade model developed in the following chapters.

Procedures

The remainder of this study is divided into six chapters. Chapter II provides a brief review of past studies on agricultural trade models. The literature review gives an idea of research needs on the area of international trade studies of agricultural commodities.

Chapter III presents a theoretical framework of the world wheat trade model. The model consists of three submodels: the trade flow model, the total import demand model, and the export supply side model. Each submodel is finally described by a set of equations, which can be empirically estimated.
Chapter IV provides the estimation procedure of the econometric model of world wheat trade. Estimation methods, statistical specification, data sources, and other problems are discussed.

Chapter V reports the estimation results of the model. The results are examined by country or region, and economic interpretations are also provided.

In Chapter VI, all of the equations estimated are incorporated into a system representing the world wheat trade model, which simultaneously solves all the prices and trade flows as well as consumption, production, and inventories in exporting countries, together with total import demands in importing regions. The model is evaluated by examining the results of historical simulation. Using the simulation model, impacts of several exogenous variables on world wheat trade are also examined.

Chapter VII presents a summary and conclusions. The important findings of the study are reviewed and the limitations of the study are discussed. Finally, the conclusions are drawn.
CHAPTER II. LITERATURE REVIEW

The world food crisis of 1972-73 motivated researchers to sharpen the studies on international trade and led to a burst of studies on agricultural commodities in the 1970s. There are a number of approaches to attack the problems in international trade of agricultural commodities. Modeling agricultural trade has been conducted in a wide range from naive two-country, single-commodity models to more sophisticated multi-region, multi-commodity models in various forms. The developments in agricultural trade models have been surveyed in several studies; for example, Adams and Behrman [4], Grennes et al. [28], Labys [52], Sarris [78], Schmitz [82], and Schuh [86]. One of the most comprehensive surveys was recently reported by Thompson [100]. He first reviewed two-region models, which are extensions of domestic agricultural sector models to include export demand or import supply relations and linkages between the domestic and world market prices. Then, he discussed multiple-region models, which are classified into nonspatial price equilibrium models, spatial price equilibrium models, and trade flow and market share models. The following review of world agricultural trade models benefited mostly from the survey by Thompson.

The world wheat trade model to be developed in this study is a single-commodity, multiple-region model, which is basically a simultaneous system of equations specifying the market relations in world wheat trade. Therefore, the review concentrates on the classes of multiple-region models used in past studies on agricultural trade, especially, on grain trade. Multiple-region models may be classified
into several types according to differences in assumptions, methods to solve the system, and purposes of the study. Following Thompson, the models reviewed here are divided into three groups: nonspatial price equilibrium models, spatial price equilibrium models, and trade flow and market share models.

Nonspatial Price Equilibrium Models

Models in this class construct a set of equations which describes market interrelationships or the structure of the market. The equations are basically sets of regional models each composed of a system of simultaneous equations. The models typically contain internal supply and demand schedules of trading regions, although these sometimes contain only one excess export supply or excess import demand schedule for each region. The prices are linked together among the regions and the models are solved simultaneously by the supply-demand balance such that the world market clears. The model structure employs an econometric methodology and parameters are statistically estimated by a limited or full information estimator, although more commonly, these are estimated by ordinary least squares. The system of equations is then solved by matrix inversion, if linear, or by an iterative procedure such as the Gauss-Seidel or the Newton-Rafson methods, if nonlinear. Models in this class assume that the excess demands and excess supplies are pooled in a world market and typically one global "world price" is formulated. However, the models can introduce transportation costs to differentiate prices among trading regions. The introduction of price differentiation gives a spatial pattern of prices, but does not generate source-
destination trade flows endogenously.

Nonspatial equilibrium models have been applied to agricultural trade by Adams and Behrman [4] for seven world commodity markets, Lattimore and Zwart [54] for the world wheat market, Abbott [1] for the world grain market, Chaipravat [14] for world rice trade, and others. Models covering a wide range of agricultural commodities have been developed by the FAO [23] for 18 commodities and 28 regions, the Japanese Ministry of Agriculture and Forestry [43] for 11 commodities and 25 regions, and the USDA [73, 75, 76] for 12 commodities and 28 regions.

Most of the nonspatial price models take a free trade view of the world agricultural markets. However, most countries have policy interventions to insulate domestic agricultural sectors from the world market. Among the trade policy variables, tariff barriers are easily introduced into the models in this class. Nontariff barriers also may be introduced in the form of quantitative restrictions in certain models. Moreover, government policy decisions may be treated endogenously in the system because policy changes are sometimes subject to the market situations. Abbott [1], Zwart and Meilke [115], and Lattimore and Zwart [54] are the examples of models that endogenize government policies.

Spatial Price Equilibrium Models

The second class of multi-region trade models is mathematical programming-based spatial price equilibrium models. This type is the most common in empirical research on agricultural trade. Most models in this class have been formulated with linear export supply and import demand schedules for the trading regions and solved by the quadratic
programming technique developed by Takayama and Judge [96, 97]. Prices, quantities traded, and a pattern of trade are determined such that "net social payoff", defined as the sum of consumer and producer surplus net of transportation costs, is maximized. The theoretical framework of the spatial price equilibrium models was first developed in a mathematical programming problem by Samuelson [77]. One advantage of the spatial price equilibrium models over nonspatial price equilibrium models is that the models in the former class endogenize trade flows and market shares. Another advantage is that quantitative restrictions on trade such as tariff barriers are introduced more easily in the form of linear inequality constraints.

This approach has been widely applied to agricultural trade analysis. Examples of the quadratic programming (QP) models include Schmitz and Bawden [83] on wheat, Thompson [99] and Janjaroen [42] on corn, and Chung [16] on feed grains. Multiple commodity models in the framework of the QP are relatively new; e.g. Takayama and Hashimoto [95], Nguyen [64], and Whitacre and Schmidt [114]. As non-QP spatial price equilibrium models, Moore et al. [62] solved the grain and beef trade problem by minimizing transportation costs, and Blakeslee et al. [10] developed a linear programming model for the world trade of grain, fertilizer, and phosphate rock.

One of the limitations in the QP formulation is that it requires linearity of export supply and import demand schedules. However, a separable programming approach or new algorithms for solving nonlinear spatial equilibrium problems have been recently developed. These
provide alternatives to the QP with less restrictive assumptions. Another limitation is concerned with trade flows generated in the models. The maximum number of trade flows permitted in the basic solution is one less than the number of restrictions in the model; therefore, the number of trade flows cannot exceed one less than the total number of exporters and importers unless quantitative restrictions are imposed. Moreover, trade flows generated in the model are very sensitive in nature to small changes in exogenous factors such as transportation costs, on which reliable data are quite difficult to find. Indeed, most of the studies do not explain real world trade flows adequately. Additionally, it should be noted that in most of the QP models, production, consumption, and marketing activities are assumed to be perfectly competitive, and distortions come about only through government policies. This does not comply with reality in most cases of agricultural trade.

Trade Flow and Market Share Models

The failure of spatial price equilibrium models to account adequately for trade flows leads to the third class of multiple-region models. In order to explain the departures of trade flows from the spatial price equilibrium framework, several hypotheses could be made. One example is that the products may not be perfectly homogeneous. In reality, there are many varieties of a kind of agricultural commodity and they are not perfect substitutes for one another. Moreover, importers may want to diversify their sources of supply because of the differences not only in physical quality, but also in reliability of supply, political alliance, historical relationship, and so on. As a
result, the law of one price in the world market does not hold in many agricultural commodities. In response to these observations, a number of models which focus on explaining changes in the elements of trade flow matrix have been developed.

There are two basic model groups approaching to trade flows or market shares. The models in the first group are those which break down past changes in the trade flows or transform the trade flow matrices from one year to the next, using mechanical procedures. This group includes constant market share models, Markov models, probability models, and transition matrix models. One shortcoming of this group is the lack of a role for prices in determination of the trade flows. The constant market share approach, which breaks down a given country's export growth into several fractions attributable to factors of market growth and market share changes, was applied to wheat exports by Rigaux [72] and Sprott [93]. Applications of Markov theory are found in Dent [19] for wool trade and Hurtado [35] for grain imports. Probabilistic trade models, following Savage and Deutsch [80], were applied to coarse grain trade by Schmidt and Vandenborre [81] and to wheat trade by Konandreas and Hurtado [50]. An application of the transition matrix approach is the model of world wheat trade by Abel and Waugh [2].

The second group of trade flow models tries to explain the trade flows with economic implications. The models in this group typically assume that the substitutability among sources of supply is not perfect. This group includes econometric models which specify equations to
explain the individual elements of the trade flow matrix. A common application has been to estimate regional import demand equations for the shipments from a given exporting country. The models, which explicitly have a parameter of substitutability among sources of supply, are sometimes called the elasticity of substitution models. This approach essentially tries to explain the determination of market shares by changes in relative prices. Such an approach has a relatively long history in empirical studies on aggregate trade or trade in manufactured goods. Applications of this approach to agricultural trade are seen in the studies by Capel and Rigaux [12] on wheat and Sirhan and Johnson [89] on cotton.

A more sophisticated theory in the framework of the elasticity of substitution models was developed by Armington [7]. Armington's model differentiates products by place of production from the consumers' viewpoint. Consumers are assumed to have weakly separable utility function so that the consumers' decision process may be viewed as occurring in two stages; first, a consumer decides the total volume to spend on the kind of product, then he allocates the volume among suppliers of the product by origin. In order to reduce the number of parameters to be estimated, a constant elasticity of substitution among suppliers is assumed. Applications of Armington's model to agricultural trade have been conducted by Grennes et al. [28] on wheat and feed grain, and Collins [17] on feed grain.
CHAPTER III. A SYSTEM OF WORLD WHEAT TRADE MODEL

Overview of Modeling Process

A principal purpose of this study is investigating the market structure and mechanism of world wheat trade with an appropriate econometric model. The model should yield changes in the pattern of world wheat trade over time. Trade flows are the key factor in determination of the trade pattern, and they reflect structural changes in the world market. Therefore, the model to be developed in this study puts the role of trade flows at the center of the system. Theoretical background of the model for trade flow analysis is based on the import demand model developed by Armington [7], which differentiates products by place of production. Validity of such differentiation of products in wheat is given by the following observations. First, varieties and quality of wheat exported vary by country; for example, exports from Argentina consist primarily of hard red wheat; Australian exports are primarily standard white; exports by Canada are largely made up of the red spring class; wheat from France is predominantly soft; and the United States provides the widest range of wheat, in which hard red winter is the dominant class exported. Secondly, wheat traded is likely to be differentiated because of the national factors such as the degree of political alliance with the exporter or the tendency to diversify the purchases of wheat for security purpose. Moreover, there are variations in harvest time across countries; wheat is harvested between February and September in the Northern Hemisphere, whereas wheat is harvested in November, December, and January in the Southern Hemisphere.
Therefore, importers may change the sources of supply by season, and even cross-hauling may occur if yearly trade flows are estimated. In this case, the trade pattern will look as if the products were differentiated.

The application of Armington's model to world wheat trade has been attempted in the past by Grennes et al. [28]. Their analysis deserves some comments. First of all, they decomposed the world into six endogenous regions and an exogenous rest of the world. The six include the four major exporters; the United States, Canada, Australia, and Argentina, and two major importers; Japan and the EEC. This decomposition, however, is not very adequate. As seen in Chapter I, the world wheat trade has increased importance of the less developed countries (LDCs) and the centrally planned economies (CPs), which were not listed in the endogenous regions in their study. The rest of the world defined in their study accounts for about 75 percent of the world wheat trade. Nevertheless, it was treated as exogenous. Second, the quantitative analysis of changes in trade flows was based on judgmental values of the parameters. Especially, the assumption of the value of the elasticity of substitution is critical; it was assumed to be 3 among all pairs of the suppliers in all markets. This value will be compared with the estimates of the elasticity of substitution obtained in the following chapter in this study. Third, the supply side of world wheat trade was treated as given. In reality, supply responses are not independent of the market situation; at least, supply responses in exporting countries should be examined. Their approach was a good challenge to the difficulties to analyze the mechanism of trade flows of
wheat. However, their model was not well-validated because of the shortcomings discussed above. Sarris [78] showed that their model did not predict trade shares as well as the naive constant market share model.

The model of world wheat trade to be developed is divided into three parts: trade flow equations, total import demand equations, and supply side equations of exports. Trade flow equations are derived from Armington's model and specified in a system of linear equations according to Hickman and Lan [32], who modified Armington's model for the estimation of elasticities of substitution. To complete the system of import demand equations requires to specify the total import demands for wheat in each market region, which are treated as given in the stage of trade flow equations. Total import demands for wheat are derived from domestic consumption and inventory changes less domestic production. In specification of the total import demand equations, special attention is paid to price and income variables because these variables have to take into account the effects of exchange rate changes. Supply side equations consist of a wheat production equation, a domestic demand equation for wheat, and a wheat inventory equation for each exporting country. Each of these equations is specified following the traditional economic theory of supply and demand. Finally, all equations are incorporated in a system representing the world wheat trade model by introducing price linkage equations, which connect export prices with import prices and market clear conditions. Therefore, the system of the model simultaneously solves all the trade flows and corresponding prices, total import demands,
aggregated export demands, and export prices as well as production,
consumption, and inventories in exporting countries. The structure of
the model is discussed in detail in the following sections.

Trade Flow Equations for Wheat

Armington's trade flow model

Following Armington's formulation, an importer's purchasing
decision is assumed to be represented by a two-stage budgeting procedure.
In the first stage, the importer, who has a weakly separable utility
function, determines expenditure on goods by maximizing

\[ U = U(Q_1, Q_2, \ldots, Q_n) \]  

subject to

\[ E = \sum_{k=1}^{\delta} Q_k P_k \]  

where \( U \) is total utility, \( E \) is total expenditure, \( Q_k \) is quantity index
for good \( k \), and \( P_k \) is price index for good \( k \). Because of the
assumption of weakly separable utility, quantity index for a given kind
of good is represented by a function of quantities of products in the
kind:

\[ Q_k = \phi_k (Q_{k1}, Q_{k2}, \ldots, Q_{kn}) \]  

where \( Q_{k1}, Q_{k2}, \ldots, Q_{kn} \) are quantities of products in good \( k \). It is
noted that "goods" are distinguished only by kind, whereas "products"
are distinguished both by kind and by place of production. Equation (3.3)
means that the importer's preference for different products of any given
kind is independent of his purchases of products of any other kind. The necessary and sufficient condition for such a weakly separable utility function is that marginal rates of substitution between any two products of the same kind must be independent of the quantities of the products of all other kinds. Now, the quantity index of demand for good \( k \), \( Q_k^* \), is derived as a function of \( n \) good price indices and total expenditure:

\[
Q_k^* = Q_k^* (P_1, P_2, \ldots, P_n, E)
\]

(3.4)

In the second stage, the demand for any product is obtained by minimizing the cost of purchasing the volume of \( Q_k^* \) just determined in the first stage; that is, the demand for product \( i \) of good \( k \), \( q_{ki}^* \), is derived by minimizing

\[
\sum_{i=1}^{n} P_{ki} q_{ki}
\]

subject to the quantity index,

\[
Q_k^* = \phi_k (Q_{k1}, Q_{k2}, \ldots, Q_{kn})
\]

(3.5)

where \( P_{ki} \) is the price of product \( i \) of good \( k \). The resulting demand function is

\[
Q_{ki}^* = Q_{ki}^* \left( \frac{P_{ki}}{P_{k1}}, \frac{P_{ki}}{P_{k2}}, \ldots, \frac{P_{ki}}{P_{kn}} ; Q_k \right)
\]

(3.7)

where \( Q_{ki}^* \) is the quantity demanded for product \( i \) of good \( k \).

In the specification of the quantity index represented by Equation (3.3), Armington introduced the constant elasticity of substitution (CES) function to simplify the model. Now, according to
his specification, the quantity index of wheat imports is also specified in the CES type, i.e.

\[ M_j^* = \left[ \sum_{i=1}^{n} a_{ij} \cdot X_{ij} \right]^{-\rho_j} \cdot \frac{1}{\rho_j} \]  

(3.8)

where \( M_j^* \) is the quantity index of wheat imports in region \( j \), \( X_{ij} \) is the quantity of imports of wheat in region \( j \) from exporter \( i \), and the elasticity of substitution between the imports in region \( j \) from any two exporters is represented by \( \sigma_j = 1/(1 + \rho_j) \). Note that the notations of subscripts are slightly changed; the subscript \( k \), which showed good \( k \), is dropped and the subscript \( j \) is introduced to show an importing region, while the subscript \( i \) remains to show an exporting country.

Given Equation (3.8), it can be shown that the cost-minimizing quantities of imports demanded for attaining a specified level of \( M_j^* \) are:

\[ X_{ij} = a_{ij} \cdot M_j^* \cdot \left( \frac{P_{ij}^*}{P_j^*} \right)^{-\sigma_j} \]  

(3.9)

where \( P_{ij}^* \) is the price of the imports of wheat in region \( j \) from exporter \( i \) and

\[ P_j^* = \left[ \sum_{i=1}^{n} a_{ij} \cdot (P_{ij}^*)^{1-\sigma_j} \right]^{1/(1-\sigma_j)} \]  

(3.10)

is the price index of imports with the property that

\[ P_j^* \cdot M_j^* = \sum_{i=1}^{n} P_{ij}^* \cdot X_{ij} = V_j \]  

(3.11)

It is noted that \( V_j \) is the actual total value of the imports of wheat.

Equation (3.9) is the basic equation for the trade flow analysis. However, it is difficult to apply Equation (3.9) directly to the
estimation of the elasticity of substitution since it is nonlinear and includes nonmeasurable parameters such as $M_j^*$ and $P_j^*$.

**Linearized trade flow equations**

Hickman and Lau [32] modified Armington's model by introducing normalization and linearizing the import demand functions, which leads to a statistical estimation of the elasticity of substitution. First, they set

$$\sum_{i=1}^{n} a_{ij} = 1$$

and all the import prices ($P_{ij}^*$'s) and import price indices ($P_{ij}^*$'s) in the base period equal to unity. Then, after a mathematical manipulation, they obtain the following import demand functions:

$$X_{ij} = \alpha_{ij}^o (P_{ij})^{-\sigma_j} \left[ \sum_{k=1}^{n} \alpha_{kj}^o (P_{kj})^{-\sigma_j} \right]^{-1} \cdot M_j$$

(3.12)

where

$$\alpha_{ij}^o = \frac{x_{ij}^o}{M_j^o} = a_{ij}$$

is the market share of exporter $i$ in the market region $j$ in the base period, $P_{ij}$ is the normalized import price, set at unity in the base period, and

$$M_j = \sum_{i=1}^{n} X_{ij}$$

is the total quantity of imports in market region $j$. Note that $M_j$ is the simple arithmetic sum of the imports from all exporting countries to market region $j$, and it should not be confused with $M_j^*$, the CES quantity.
index of imports. Equation (3.12) is an exact expression for any given level of the total quantity of imports.

Hickman and Lau linearize Equation (3.12) in the $P_{ij}$'s and $M_j$ by a Taylor's series expansion around $P_{ij} = 1$, for all $i$ and $j$, and $M_j = M_j^0$, the base period total imports. Finally, they derive a linear import demand equation in region $j$ from exporter $i$ as follows:

$$X_{ij} = \alpha_{ij}^0 \cdot M_j - \sigma_j \cdot X_{ij}^0 \cdot (P_{ij} - P_j) \quad (3.13)$$

where

$$P_j = \sum_{k=1}^{n} \alpha_{kj}^0 \cdot P_{kj} \quad (3.14)$$

is a new import price index having the interpretation of a fixed-weighted average of the export prices of all exporters in market region $j$. It can be seen that individual import demand functions given in Equation (3.13) have the adding-up property, i.e.

$$\sum_{i=1}^{n} X_{ij} = M_j$$

Therefore, in the system of equations given in Equation (3.13), the equations are not all independent. Only $(n-1)$ equations for each $j$ are independent, where $n$ is the number of exporters in market region $j$.

Equation (3.13) can be applied to the estimation of the elasticity of substitution if data of trade flows and corresponding import prices are available.

**Introducing shift variables**

In the application of the linear system by Hickman and Lau to world wheat trade, three shift variables are introduced to take into account
preference changes in importers over time. The variables to explain the shifts of preferences are as follows:

(i) A dummy variable $D$ such that

$$D = 0 \text{ if year < 1973}$$
$$= 1 \text{ if year } \geq 1973.$$  

(ii) An integer variable $T$ representing time trend, set at zero in base period.

(iii) A time dummy variable $TD$ such that

$$TD = 0 \text{ if year < 1973}$$
$$= T \text{ if year } \geq 1973.$$  

The dummy variable $D$ explains a shift of the basic preference parameter, $a_{ij}$ in Equation (3.8), from the period before 1973 to the period after 1973, in which the so-called world food crisis took place and it is said that the world market structure of grain trade has been changed since that year. The integer variable $T$ explains the trend of changes in preferences over time, and the time dummy variable $TD$ is introduced to show a change in the slope of the time trend since 1973.

The introduction of these shift variables requires the rewriting of the CES quantity index of imports as follows:

$$M_j^* = \left[ \sum_{i=1}^{n} A_{ij} \cdot X_{ij} \right]^{(\sigma_j - 1)/\sigma_j} \sigma_j^{\sigma_j/(\sigma_j - 1)} \tag{3.15}$$

where

$$A_{ij} = a_{ij} \cdot \exp (b_{ij} \cdot T + c_{ij} \cdot TD + d_{ij} \cdot D) \tag{3.16}$$

Note that $\exp$ represents the exponential function.
A similar derivation applies to Equation (3.15) to obtain the individual import demand functions. Then, the exact expression of the functions is given by:

\[
X_{ij} = \alpha_{ij}^O \cdot \exp \left( \sigma_j^i \cdot b_{ij} \cdot T + \sigma_j^i \cdot c_{ij} \cdot TD + \sigma_j^i \cdot d_{ij} \cdot D \right) \cdot P_{ij}^{-\sigma_j^i} \\
\cdot \left[ \sum_{k=1}^{n} \alpha_{kj}^O \cdot \exp \left( \sigma_j^i \cdot b_{kj} \cdot T + \sigma_j^i \cdot c_{kj} \cdot TD + \sigma_j^i \cdot d_{kj} \cdot D \right) \cdot P_{kj}^{-\sigma_j^i} \right]^{-1} \cdot M_{ij}
\]

Equation (3.17) is also linearized by a Taylor's series expansion around \( P_{ij} = 1 \), for all \( i \) and \( j \), \( M_j = M_j^0 \), \( T = 0 \), \( TD = 0 \), and \( D = 0 \). Thus, the final form of the individual import demand equations for wheat differentiated by origin becomes:

\[
X_{ij} = \alpha_{ij}^O \cdot M_j - \sigma_j^i \cdot X_{ij}^O \cdot (P_{ij} - P_j) \\
+ \sigma_j^i \cdot \beta_{ij} \cdot X_{ij}^O \cdot T + \sigma_j^i \cdot \gamma_{ij} \cdot X_{ij}^O \cdot TD + \sigma_j^i \cdot \delta_{ij} \cdot X_{ij}^O \cdot D
\]

(3.18)

where

\[
\beta_{ij} = b_{ij} - \sum_{k=1}^{n} \alpha_{kj}^O \cdot b_{kj}
\]

(3.19)

\[
\gamma_{ij} = c_{ij} - \sum_{k=1}^{n} \alpha_{kj}^O \cdot c_{kj}
\]

(3.20)

and

\[
\delta_{ij} = d_{ij} - \sum_{k=1}^{n} \alpha_{kj}^O \cdot d_{kj}
\]

(3.21)

The real coefficient for preference changes over time for the period after 1973 is obtained by adding the coefficient of TD to the coefficient of T.
It is noted that in the system of equations given in Equation (3.18), the equations are not all independent because of the adding-up condition. Therefore, the shift parameters are constrained as follows:

\[ \sum_{i=1}^{n} \alpha_{ij}^o \beta_{ij} = \sum_{i=1}^{n} \alpha_{ij}^o \gamma_{ij} = \sum_{i=1}^{n} \alpha_{ij}^o \delta_{ij} = 0 \]

Equation (3.18) represents a linear system of wheat import demands for individual trade flows and it is a first order approximation of a theoretical demand model of the Armington type, including trend terms and dummy variables to show preference changes. Therefore, the estimated coefficients corresponding to the relative price variables in the system are interpreted as the elasticities of substitution between imports in given regions. The equations given in Equation (3.18) are, hereafter, referred to as the trade flow equations.

**Total Import Demand for Wheat**

The determination of the total import demand for wheat in each market region, which was considered as predetermined in the trade flow equations, is discussed in the framework of the traditional derived import demand theory. In general, import demand is represented by domestic consumption and inventory changes less domestic production. For time period \( t \), the relationship is given by:

\[ M_t = TCS_t + TST_t - TST_{t-1} - TQ_t \]  \hspace{1cm} (3.22)

where \( M_t \) is the total imports, \( TCS_t \) is the total consumption, \( TST_t \) is the inventory level at year end, and \( TQ_t \) is the total production. Note
that the subscript \( j \) to show a market region is omitted for awhile. The wheat trade model in this study assumes that the domestic wheat production in each market region is exogenous because most wheat-importing countries insulate their producers from competition with imports by government policies. The factors influencing consumption and inventories are discussed and they are combined to obtain the total import demand functions for wheat.

**Consumption demand**

The specification of consumption demand for wheat is straightforward from consumer demand theory, which shows the outcome for a utility-maximizing consumer who faces known prices and a fixed income when making commodity purchase decisions. An individual's wheat demand is related to wheat price, price of substitutes, and income:

\[
CS_t = f(PM_t, PS_t, YE_t) \quad (3.23)
\]

where \( CS_t \) is the per capita consumption of wheat, \( PM_t \) is the real price of wheat, \( PS_t \) is the real price of substitutes, and \( YE_t \) is the real per capita income. If the function is specified in the linear form, the individual demand equation is:

\[
CS_t = a_0 + a_1 PM_t + a_2 PS_t + a_3 YE_t . \quad (3.24)
\]

Under the assumption of identical consumer preference, total consumption demand for wheat is obtained by just multiplying the individual demand by population, \( N_t \):
Wheat consumption is sometimes divided into two terms by usage: human consumption and feed use. Indeed, wheat is used for animal feed in many developed countries depending on price relationships, whereas in the less developed countries, wheat is used almost exclusively for human consumption. In this study, wheat demands are conceptually aggregated and the relationship with livestock sector is taken into account for the developed countries by introducing feed grain prices as the price of substitutes.

Inventories

Assuming that most of the inventories of wheat in importing regions are for transactions, wheat demand for ending inventories is specified on the basis of the so-called accelerator model, according to which, inventories vary directly and proportionately with production. The accelerator model is modified to include the partial adjustment of inventories to production. If the desired level of inventories, TST* , is represented by

$$TST_t^* = \alpha \cdot TQ_t$$

(3.26)

and the actual inventories are adjusted only a fraction of the distance required to reach the desired level, as shown by

$$TST_t - TST_{t-1} = \beta(TST_t^* - TST_{t-1}), \quad 0 < \beta \leq 1,$$

(3.27)

then the final expression for inventory demand is
Derived import demand

Combining Equations (3.24), (3.25), and (3.28) with Equation (3.22), and dividing both sides of the equation by population, \( N_t \), the per capita wheat import demand equation is obtained:

\[
\frac{M_t}{N_t} = a_0 + a_1 \cdot PM_t + a_2 \cdot PS_t + a_3 \cdot YE_t \cdot \beta \frac{TST_{t-1}}{N_t} - (1 - \alpha \beta) \frac{TQ_t}{N_t}
\]  

(3.29)

or

\[
MQt = b_0 + b_1 \cdot PM_t + b_2 \cdot PS_t + b_3 \cdot YE_t + b_4 \cdot ST_{t-1} + b_5 \cdot Qt
\]  

(3.30)

where \( MQt \) is the per capita imports of wheat, \( ST_{t-1} \) is the lagged ending inventories of wheat divided by population, and \( Qt \) is the per capita production of wheat. Expected signs of the coefficients in Equation (3.30) are as follows: \( b_1 < 0, b_2 > 0, b_4 < 0, b_5 < 0 \), and \( b_0 \) and \( b_3 \) are not predetermined.

The wheat trade model in this study concerns commercial trade of wheat. However, noncommercial exports have historically played an important role in world wheat trade, although their importance has presently declined. Noncommercial shipments, most of which have been managed by the U.S. government under PL 480 programs, influence recipient countries' wheat economies in the same manner as an increase in domestic supplies. Consequently, substitution between wheat imported on
a commercial basis and wheat imported on a noncommercial basis is expected. Therefore, the amount of noncommercial imports is introduced as an exogenous variable in the model for the less developed countries. Then, Equation (3.30) is rewritten for the LDCs as:

\[ MQ_t = b_0 + b_1 PM_t + b_2 PS_t + b_3 YE_t + b_4 ST_{t-1} + b_5 Q_t + b_6 A_t \]  

(3.30a)

where \( A_t \) is the per capita noncommercial imports of wheat, and \( b_6 \) is expected to be negative. For the same reason, imports of wheat in Eastern Europe from the USSR are treated as noncommercial imports and introduced exogenously in the model.

**Price and income variables**

In estimating the per capita import demand equations given in Equation (3.30) or Equation (3.30a), special attention is paid to price and income variables because the estimation is applied to groups of countries, which have different units of currencies. It is essential to have prices and incomes specified in common units when considering different countries. Monetary variables should be expressed on a common currency basis combining exchange rates and prices. The treatments of monetary variables in this study are similar to those given by Konandreas et al. [51].

First of all, the "effective" consumer price index is defined in terms of the common currency unit, U.S. dollars, for each market region as follows:
\[
CPE_t = \sum_{k=1}^{k'} w^k \frac{[CPI^k_t/100]}{(ER^k_t/ER^0_t)}
\]  

(3.31)

where \( CPE_t \) = "effective" consumer price index for a given region,
\( CPI^k_t \) = consumer price index of the \( k \)-th country in the region, expressed with a base = 100,
\( ER^k_t \) = exchange rate expressed in the \( k \)-th country's currency per U.S. dollar,
\( ER^0_t \) = exchange rate in the base year,
\( w^k \) = average import share of the \( k \)-th country's imports within the total imports of the region, and
\( k' \) = number of importing countries in the region.

Based on the "effective" consumer price index for a given region, the price variables in the import demand equation are defined as follows:

\[
PM_t = P_t/CPE_t
\]

(3.32)

where \( PM_t \) is the "effective" real price of wheat in the region, and \( P_t \) is the market price of wheat, equated to the import price index defined in Equation (3.14), which is based on the import prices expressed in U.S. dollars;

\[
PS_t = PA_t/CPE_t
\]

(3.33)

where \( PS_t \) is the "effective" real price of the substitutes for wheat in the region, and \( PA_t \) is the market price of the substitutes, equated to the import price of feed grain for the DCs, or the import price of rice for the LDCs, both expressed in U.S. dollars.
In the same manner, the income variable is defined as:

\[
YE_t^k = \sum_{k=1}^{k} \omega_k YI_t^k / \left[ \frac{(CPI_t^k / 100)}{(ER_t^k / ER_0^k)} \right] \quad (3.34)
\]

where \( YE_t^k \) is the "effective" real income per capita in the region, and \( YI_t^k \) is the nominal income per capita expressed in U.S. dollars in the \( k \)-th country in the region.

Supply Side Equations of Wheat Exports

Export supply of a given country is derived from the market relationships in the country. The relationship given in Equation (3.22) can be applied to exporting countries as well, if negative imports are interpreted as exports. The basic components of the domestic market are production, domestic demand, and inventories. In modeling the supply side of wheat trade, these components are specified separately for each exporting country.

Production

The theory underlying production is the producer's supply response to price, which depends on profit maximization subject to given production functions, prices, and weather conditions. Let the production function for wheat be written as:

\[
PD = f(F, L, T, W) \quad (3.35)
\]

where \( PD \) is production of wheat, \( F \) is variable inputs such as fertilizer, \( L \) is land, \( T \) is time trend showing technological change, and \( W \) is weather index having expected value of zero.
Suppose that the production decision is made in two stages. First, farmers decide on the acreage of land to plant wheat. Later, they decide the level of other inputs. Given the decision of planting acreage, which may depend on expected prices, government programs, crop rotation requirements, and others, farmers maximize their expected profits defined as:

$$\pi^e = P^e \cdot PD^e - P^f \cdot F$$  \hspace{1cm} (3.36)$$

where $\pi^e$ is the expected profits, $P^e$ is the expected price of wheat, $P^f$ is the price of variable inputs, and $PD^e$ is the expected level of wheat production, which is obtained by setting $W$ equal to zero in Equation (3.35). The first order condition of this maximization with respect to the variable inputs gives the demand for the variable inputs, which can be written as:

$$F = F(P^e/P^f, L^*, T)$$  \hspace{1cm} (3.37)$$

where $L^*$ is the acreage of land already decided. The price ratio appears because the profit maximization requires that the marginal physical products of the variable inputs be equated to the input-output price ratio. Substitution of this level of the variable inputs back into the production function given in Equation (3.35) gives a general supply function, which is expressed as:

$$PD = g(P^e/P^f, L^*, T, W)$$  \hspace{1cm} (3.38)$$
Now, the acreage response relation is introduced in the supply function. It is assumed that the farmers' planting decisions are mainly influenced by the expected price ratios of wheat to the variable inputs and to other crops and government programs. Then, the relationship is represented by

\[ L^* = L^*(P^e/P^f, P^e/P^c, G) \] (3.39)

where \( P^c \) is the price of other crops and \( G \) is an indicator such as a dummy variable to represent the government programs affecting the planting decision. Combining Equations (3.38) and (3.39) gives the supply function including the acreage response:

\[ PD = g(P^e/P^f, P^e/P^c, T, W, G) \] (3.40)

In estimating the supply functions given in Equation (3.40), a linear functional form is assumed and the price expectation is assumed to be based on the prices available before planting. Thus, the wheat production equations to be estimated are represented by

\[ PD_t = b_0 + b_1 \cdot (\frac{PW}{PF})_{t-1} + b_2 \cdot (\frac{PW}{PC})_{t-1} + b_3 \cdot T + b_4 \cdot W_t + b_5 \cdot G \] (3.41)

where \( PW \) is the market price of wheat, equated to the export price of wheat, \( PF \) is the price index of the variable inputs, and \( PC \) is the price of alternative crops. Expected signs of the coefficients are as follows: \( b_0 \) is not predetermined, \( b_1 > 0, b_2 > 0, b_3 > 0, b_4 > 0, \) and \( b_5 \) depends on the policy purpose of the program.
Domestic consumption

The derivation of the domestic consumption demand for wheat in exporting countries is the same as discussed for the total import demand for wheat. The wheat demands for human consumption and for feed use are aggregated, and the per capita wheat demand, $CS_t$, is expressed in the linear function as:

$$CS_t = b_0 + b_1 \cdot \frac{PW_t}{CPI_t} + b_2 \cdot \frac{PL_t}{CPI_t} + b_3 \cdot Y_t$$  \hspace{1cm} (3.42)

where $PW$ is the market price of wheat, equated to the export price, $PL_t$ is the price of livestock, $CPI$ is the consumer price index, and $Y_t$ is the per capita real income. Expected signs of the coefficients are as follows: $b_1 < 0$, $b_2 > 0$, and $b_0$ and $b_3$ are not predetermined.

Inventories

The inventory equations for exporting countries are specified to include speculative inventory behavior. For this purpose, the accelerator model is modified by introducing a price variable. Assuming that the price expectation is based on the current price, the desired level of inventories, $IN^*_t$, is represented by

$$IN^*_t = \alpha_0 + \alpha_1 \cdot PD_t + \alpha_2 \cdot PW_t$$  \hspace{1cm} (3.43)

where $PD_t$ is production of wheat for the transactions demand, and $PW_t$ is the market price of wheat, equated to the export price, for the speculative demand. The coefficient $\alpha_1$ is expected to be positive, whereas the coefficient $\alpha_2$ is expected to be negative. If the price is "high", it can be expected to fall; if the price is "low", it can be
expected to rise, providing incentives for inventory decumulation or accumulation, respectively.

The partial adjustment hypothesis is again introduced, and the adjustment function is given by

\[ IN_t - IN_{t-1} = \beta \cdot (IN_t^* - IN_{t-1}), \quad 0 < \beta \leq 1. \]  \tag{3.44}

Substituting Equation (3.43) into Equation (3.44) gives the final expression of the inventory demand equation:

\[ IN_t = \alpha_0 \cdot \beta + \alpha_1 \cdot \beta \cdot PD_t + \alpha_2 \cdot \beta \cdot PW_t + (1 - \beta) \cdot IN_{t-1} \]  \tag{3.45}

or

\[ IN_t = b_0 + b_1 \cdot PD_t + b_2 \cdot PW_t + b_3 \cdot IN_{t-1} \]  \tag{3.46}

where \( b_1 \) and \( b_3 \) are expected to be positive, \( b_2 \) negative, and \( b_0 \) not predetermined.

Total System of the Wheat Trade Model

The equations developed in the preceding sections are incorporated into a system of the world wheat trade model. The system of the model is closed by introducing the price linkage equations, by which the individual import prices are linked to the export prices, and the quantity balance equations, which make the market cleared. The total system of the wheat trade model is summarized by rewriting the concerning equations in general form ignoring the restrictions on the coefficients. The equations are as follows:
Importing regions

(1) Per capita total wheat import demand:

$$MQ_j = a_{0j} + a_{1j} \cdot \frac{P_4}{CPE_j} + a_{2j} \cdot \frac{FA_j}{CPE_j} + a_{3j} \cdot YE_j$$

$$+ a_{4j} \cdot ST_{j,-1} + a_{5j} \cdot Q_j + a_{6j} \cdot A_j$$

(2) Total import demand:

$$M_j = N_j \cdot MQ_j$$

(3) Trade flow equations:

$$X_{ij} = S_{ij} \cdot M_j \cdot \sigma_j \cdot B_{ij} \cdot (P_{ij} - P_j) + b_{2ij} \cdot T + b_{3ij} \cdot TD + b_{4ij} \cdot D$$

(4) Normalized import price:

$$P_{ij}^X = P_{ij}^X / P_{ij}$$

(5) Import price index:

$$P_j = \sum_{i=1}^{n} S_{ij} \cdot P_{ij}$$

Exporting countries

(6) Production:

$$PD_i = C_{0i} + C_{1i} \cdot \left( \frac{PW_i}{PF_i} \right) + C_{2i} \cdot \left( \frac{PW_i}{PC_i} \right) - 1 + C_{3i} \cdot T$$

$$+ C_{4i} \cdot W_i + C_{5i} \cdot C_i$$
(7) Per capita domestic demand:

\[ CS_i = d_{01} + d_{11} \frac{PW_i}{CPI_i} + d_{21} \frac{PL_i}{CPI_i} + d_{31} Y_i \]

(8) Total domestic demand:

\[ DC_i = N_i \cdot CS_i \]

(9) Inventories:

\[ IN_i = e_{01} + e_{11} \cdot PD_i + e_{21} \cdot PW_i + e_{31} \cdot IN_{i,-1} \]

Market relations

(10) Price linkage:

\[ P_{ij} = f_{0ij} + f_{lij} \frac{PW_i}{ER_i} \]

(11) Aggregate export demand:

\[ X_i = \sum_{j=1}^{m} X_{ij} + \sum_{j=1}^{m} AD_{ij} \]

(12) Quantity balance:

\[ PD_i + IN_{i,-1} - IN_i - DC_i - X_i = 0 \]

where \( S_{ij}, B_{ij} \) and \( P^O_{ij} \) are the market share, the exports, and the export price, respectively, of country \( i \) in region \( j \) in the base period, and \( \sigma_j \) is the elasticity of substitution in region \( j \). Note that the subscripts \( i \) and \( j \) denote an exporting country and an importing region, respectively, and the variables with the subscript \(-1\) are lagged variables. The variables are denoted as follows.
Endogenous variables:

- $MQ_j$ = per capita import demand for wheat in commercial trade in region $j$,
- $M_j$ = total imports of wheat in region $j$,
- $X_{ij}$ = individual import demand in region $j$ for wheat from country $i$,
- $PD_i$ = production of wheat in country $i$,
- $CS_i$ = per capita domestic demand for wheat in country $i$,
- $DC_i$ = total consumption of wheat in country $i$,
- $IN_i$ = wheat inventories in country $i$,
- $X_i$ = aggregate export demand for wheat produced in country $i$,
- $P_j$ = import price index of wheat in region $j$, based on U.S. dollars,
- $P^X_{ij}$ = import price in region $j$ of wheat from country $i$, expressed in U.S. dollars,
- $P_{ij}$ = normalized import price in region $j$ of wheat from country $i$,
- $PW_i$ = export price of wheat in country $i$, expressed in the currency of country $i$.

Exogenous variables:

- $PA_j$ = price of substitutes for wheat in region $j$,
- $CPE_j$ = effective consumer price index in region $j$,
- $YE_j$ = effective per capita real income in region $j$,
- $ST_{j,-1}$ = lagged ending inventories of wheat divided by population in region $j$,
- $Q_j$ = per capita production of wheat in region $j$,
\( A_j \) = per capita noncommercial imports of wheat in region \( j \),
\( N_j \) = population in region \( j \),
\( T \) = time trend set at zero in base period,
\( TD \) = time dummy variable equated to \( T \) if year \( \geq 1973 \), 0 otherwise,
\( D \) = dummy variable taking 1 if year \( \geq 1973 \), 0 otherwise,
\( PF_i \) = price index of variable inputs in country \( i \),
\( FC_i \) = price of alternative crops in country \( i \),
\( W_i \) = weather index in country \( i \),
\( G_i \) = dummy variable for government programs in country \( i \),
\( PL_i \) = price of livestock in country \( i \),
\( CPI_i \) = consumer price index in country \( i \),
\( Y_i \) = per capita real income in country \( i \),
\( N_i \) = population in country \( i \),
\( ER_i \) = exchange rate of country \( i \), expressed in the currency of country \( i \) per U.S. dollar,
\( AD_{ij} \) = noncommercial exports of wheat from country \( i \) to region \( j \).

It is noted that the model includes two lagged endogenous variables, \( PW_{i,-1} \) and \( IN_{i,-1} \), which are predetermined for the current operation of the system.

The model consists of \( (m + 3n + 2mn) \) behavioral equations, \( (2m + 2n + mn) \) definitions and \( n \) identities, where \( m \) is the number of importing regions and \( n \) is the number of exporting countries. The model is applied to the ten importing regions and the five exporting countries; therefore, the number of equations in this original system is 210, and the same number of the endogenous variables are solved in the system.
CHAPTER IV. ESTIMATION PROCEDURE

Consideration of Estimation Methods

This chapter presents the estimation procedure of the world wheat trade model developed in the preceding chapter including consideration of estimation methods, statistical specification, data description, and some other notes on the estimation. The first consideration on the estimation is statistical specification of the equations and selection of the appropriate estimation method. The model developed in this study is a system of simultaneous equations. Therefore, when error terms are introduced into the equations, any endogenous variables included on the right-hand side of the equations are jointly determined with the error terms of the equations. Application of ordinary least squares (OLS) in such a case results in biased and inconsistent parameter estimates. A limited or full information estimator is required to obtain consistent parameter estimates. However, the number of exogenous and predetermined variables in the model in this study is very large and easily exceeds the number of observations available. This causes difficulty, for example, in using two-stage least squares (2SLS) because it is required in the first stage to regress every endogenous variable on all exogenous and predetermined variables in the system. This difficulty may be handled by using the instrumental variables (IV) estimation technique. A problem posed by this IV estimation technique is the choice of the appropriate instrument to be used. The instrumental variable must be exogenous to all other equations except the equation to be estimated. On the other hand, OLS should not be totally rejected as an estimation
technique for simultaneous-equation systems while it yields biased and inconsistent estimators. The OLS estimators tend to exhibit both efficiency and insensitivity to specification error. (See Intriligator [39].) Furthermore, as little is known concerning the finite-sample properties of any estimator, OLS may be as good as any other method of estimation. As a matter of fact, the OLS method is used in estimating many simultaneous-equations systems and it is an accepted tradition in trade analysis.

The estimation procedure in this study is divided into four parts: estimation of the trade flow equations, estimation of the per capita import demand equations, estimation of the supply side equations, and estimation of the price linkage equations. The first two parts employ the two-stage estimation procedure of Zellner, the so-called "seemingly unrelated regressions (SUR)" technique, which takes into account the correlation of the disturbance terms among the equations. The trade flow equations are grouped in each region, and all the total import demand equations are grouped as a set of equations in the estimation. Other two parts, supply side equations and price linkage equations, employ the OLS method and each equation is estimated separately. If the serial correlation is found in disturbance terms, then the ordinary least squares corrected for autocorrelation (ALS) method is employed. It is noted that these methods are not free from the simultaneous-equations bias, which should be appropriately considered in interpreting the estimation results.
Trade flow equations

For the estimation purpose, Equation (3.18) is rewritten with the term $\alpha_{ij}^0 \cdot M_j$ transferred to the left-hand side and the additive stochastic disturbance term, $e_{ijt}$, is introduced into the equation.

\[
X_{ijt} - \alpha_{ij}^0 \cdot M_j t = - \sigma_j \cdot X_{ij}^0 \cdot (P_{ijt} - P_{jt})
+ \sigma_j \cdot \beta_{ij} \cdot X_{ij}^0 \cdot T + \sigma_j \cdot \gamma_{ij} \cdot X_{ij}^0 \cdot TD
+ \sigma_j \cdot \delta_{ij} \cdot X_{ij}^0 \cdot D + e_{ijt}
\tag{4.1}
\]

where the subscript $t$ refers to the time period of the observation. It is noted that the dependent variable in Equation (4.1) shows the effects of market share changes on individual trade flows because it is rewritten as $(\alpha_{ijt} - \alpha_{ij}^0) \cdot M_j t$, which is the change in market share weighted by the current market size, where $\alpha_{ijt}$ is the market share in region $j$ of country $i$ at time $t$. This term is sometimes called the "competitiveness effect" of export growth in the constant market share analysis. (See Richardson [71].)

It is assumed that the disturbance term has zero expectation, that the variances and contemporaneous covariances are constant over time, and that all other covariances vanish:

\[
E (e_{ijt}) = 0
\]

and

\[
E (e_{ijt} e_{kjs}) = \omega_{ikj}
\]

\[
= 0 \quad \text{for } t = s
\]

\[
= 0 \quad \text{for } t \neq s
\]
In other words, the disturbances of the market share change effects on trade flows are correlated to each other in a given region, but not serially correlated.

Since the equations for each region \( j \) given in Equation (4.1) are not all independent because of the adding-up condition, summing both sides of Equation (4.1) over \( i \) leads to the interdependency of the disturbance terms:

\[
\sum_{i=1}^{n} e_{ijt} = 0.
\]

This means that the variance-covariance matrix for \( e_{ijt} \) is singular. If the estimation procedure is to be efficient, this disturbance covariance must be taken into account. Therefore, for the estimation purpose, one equation from the system of equations for each \( j \) given in Equation (4.1) must be deleted arbitrarily. Only \( (n-1) \) equations are required for a complete econometric model of individual import demands in each market. The parameters of the \( n \)-th equation, which is deleted, are derived from the parameters of the other \( (n-1) \) equations to be estimated. In the real estimations, the equation of trade flow from the United States in each market region is arbitrarily dropped and the coefficients of the equation dropped are derived from other coefficients to be estimated. The estimation method applied is the seemingly unrelated regressions (SUR) technique and the elasticity of substitution, \( \sigma_{j} \), is set to be equal across all \( (n-1) \) equations for each market region \( j \). The assumptions of no serial correlation in the disturbance term and the equality of the elasticity of substitution in a given region can be
tested by using the first-stage OLS estimates.

**Per capita total wheat import demand equations**

The total import demand equations on per capita base, given in Equation (3.30), is specified including the disturbance term, $u_j$, as follows:

$$M_Ojt = b_{0j} + b_{1j} \cdot PM_{jt} + b_{2j} \cdot PS_{jt} + b_{3j} \cdot YE_{jt} + b_{4j} \cdot ST_{jt-1}$$

$$+ b_{5j} \cdot Q_{jt} + u_{jt}.$$  \hspace{1cm} (4.2)

It is again assumed that the disturbances are contemporaneously correlated to each other because it is plausible to assume that there are disturbance factors affecting the import demand functions of more than one region at once; for example, effects of multi-lateral trade negotiations, effects of world-wide political events, expectations on world economies, and so on. Furthermore, changes in transportation costs play the same role as changes in import prices in the same direction. The transportation costs are linked all over the world, mainly depending on the energy prices. However, the model in this study considers the changes in transportation costs as random disturbances because, as discussed in the following section, the price data available corresponding to the trade flows are based on the FOB (free on board) prices, which exclude the transportation costs. Therefore, taking into account the contemporaneous correlations of the disturbance terms is a necessary procedure in the estimation. The disturbance term is specified as follows:

$$E(u_{jt}) = 0$$
and
\[ E(u_{jt} u_{ks}) = w_{jk} \quad \text{for } t = s \]
\[ = 0 \quad \text{for } t \neq s. \]

All the equations given in Equation (4.2) are estimated as a set of equations by the SUR technique without any restrictions. The assumption of no serial correlation in the disturbance term can be checked by using the first-stage OLS estimates.

**Supply side equations**

The supply side equations of wheat exports are specified by adding the disturbance terms, \( v_{it}^1, v_{it}^2, \) and \( v_{it}^3, \) to the structural equations defined in Equations (3.41), (3.42), and (3.46), respectively, as follows:

\[
PD_{it} = c_{01} + c_{11} \cdot \left( \frac{PW_i}{PF_i} \right)_{t-1} + c_{21} \cdot \left( \frac{PW_i}{PC_i} \right)_{t-1} + c_{31} \cdot T
+ c_{41} \cdot W_i + c_{51} \cdot G_i + v_{it}^1 \quad (4.3)
\]

\[
CS_{it} = d_{01} + d_{11} \cdot \left( \frac{PW_i}{CPI_i} \right)_{t-1} + d_{21} \cdot \left( \frac{PL_i}{CPI_i} \right)_{t-1} + d_{31} \cdot Y_{it} + v_{it}^2 \quad (4.4)
\]

and
\[
IN_{it} = e_{01} + e_{11} \cdot PD_{it} + e_{21} \cdot PW_{it} + e_{31} \cdot IN_{it-1} + v_{it}^3 \quad (4.5)
\]

The disturbance terms are assumed to have zero expectation and finite covariance matrix. Furthermore, it is assumed that the disturbances are identically and independently distributed:

\[ E(v_{it}^k) = 0 \]

and
\[ E(v_{it}^k v_{is}^k) = (\sigma_i^k)^2 \quad \text{for } t = s \]
\[ = 0 \quad \text{for } t \neq s, \]
where the superscript \( k \) shows a different set of equations; \( k = 1, 2, 3 \). The equations given in Equations (4.3), (4.4), and (4.5) are estimated by using the OLS method. It is noted that if the simultaneous-equations bias is ignored, the application of the OLS method to Equation (4.5) may yield consistent and asymptotically efficient estimators, but they are still biased in small samples because the equation includes the lagged dependent variable, \( IN_{it-1} \), on the right-hand side. (See Johnston [48].)

The assumption of no serial correlation for the disturbances is tested by using the Durbin-Watson d statistics. If the hypothesis of nonautocorrelated disturbance term is rejected, then the equation is reestimated by the ordinary least squares corrected for autocorrelation (ALS) method, which takes into account the autocorrelations of the disturbances. Then, the assumptions on the disturbance term are changed. The disturbance term, \( v_{it}^k \), is assumed to follow a first-order autoregressive scheme:

\[
    v_{it}^k = \rho_i^k v_{it-1}^k + e_{it}^k
\]

(4.6)

where \( |\rho_i^k| < 1 \) and \( e_{it}^k \) satisfies the assumptions

\[
    E(e_{it}^k) = 0
\]

and

\[
    E(e_{it}^k e_{is}^k) = (\sigma_{ei}^k)^2
    
    = 0
    
    \text{for } t = s
    
    \text{for } t \neq s.
\]

These assumptions can be rewritten in the following heteroscedasticity of the disturbance term \( v_{it}^k \):
\[ E(v_{1t}^k) = 0 \]

and
\[ E(v_{1t}^k v_{1s}^k) = (\rho_1^k)^{t-s} (\sigma_1^k)^2 \]

where
\[ (\sigma_1^k)^2 = \frac{(c_{1d})^k}{1 - \rho_1^k} \quad \text{for all } t. \]

The Durbin-Watson test is not applicable for an equation which includes a
lagged dependent variable on the right-hand side. Then, the Durbin-Watson
test is replaced by an alternative test based on the "h statistic",
developed by Durbin [21].

**Price linkage equations**

The price linkage equations are specified including the disturbance
term, which has the same nature as those in the supply side equations,
as follows:

\[ P_{ijt}^X = f_{0ij} + f_{1ij} \cdot \left( \frac{PW_i}{ER_i} \right) + v_{it} \quad (4.7) \]

The price linkage equation simply connects the wheat export price of a
given exporting country \((PW_i)\) converted in U.S. dollar terms by the
exchange rate \((ER_i)\) with the individual import price \((P_{ij}^X)\) corresponding
to a trade flow from the exporting country. If the data of domestic
market prices of wheat in importing regions are available by country of
origin or place of production, the equations can easily include
transportation costs and trade barriers such as tariffs. If only the
FOB-based price data are available like in this study, then the price
linkage equations may be considered as equations to represent the
structure of price discriminations by exporting countries. Changes in
trade policies in exporting countries such as grain embargoes can be introduced if they are measured in the form which can be translated as price changes.

The disturbance term, \( \nu_{1t}^4 \), is assumed to have statistically the same nature as those in the supply side equations; therefore, the explanations on the disturbance term are the same as provided in the section of the supply side equations if setting \( k = 4 \). The price linkage equations given in Equation (4.7) are estimated by the OLS method or the ALS method.

Data Sources and Problems

The data requirements for building a world trade model in even one commodity are very large. There is no single publication or data bank to cover all the necessary data in this study. The data are collected from several different sources. The basic sources of data are the United Nations (UN), the Food and Agriculture Organization of the United Nations (FAO), the International Wheat Council (IWC), the Organization for Economic Cooperation and Development (OECD), and the United States Department of Agriculture (USDA).

The estimation of the trade flow equations requires data on trade flows by regions and countries of origin and destination and data on corresponding import prices. The data source for trade flows and import prices is Commodity Trade Statistics [103] by the UN, which provides figures of quantity and value on world commodity trade by regions and countries of origin and destination. The import prices corresponding to the trade flows are approximated by unit values which are obtained by
dividing import value by import quantity. Import values in the statistics are based on FOB prices; therefore, the calculated unit values are considered as approximate FOB prices. The data for wheat trade are drawn from category 041 in the Standard International Trade Classification (SITC); it includes wheat and meslin unmilled, so trade of wheat flour is not included in this study. The data are based on calendar year; therefore, all the corresponding annual data in the analysis must be based on calendar year. As supplements, the following statistics for trade flow data are also referred to: Foreign Trade Statistics [66] by the OECD, World Grain Trade Statistics [26] by the FAO, and World Wheat Statistics [38] by the IWC.

The model in this study is concerned with only commercial trade of wheat to analyze the market mechanism in world trade. However, none of the above statistics on wheat trade differentiates commercial shipments from noncommercial shipments. In this study, the wheat exports under PL 480 programs by the United States, which are the major source of noncommercial shipments, are subtracted from the exports of the U.S. to each market region. Data of the PL 480 shipments by destination are drawn from Wheat Situation [111] and other publications on PL 480 exports [107, 110] by the USDA; the data are rearranged to get based on calendar year and converted into metric tons.

For the per capita total wheat import demand equations, in addition to the data for the trade flow equations, data of importing countries are required on consumer price index, exchange rate, per capita income, price of substitutes for wheat, production of wheat, ending inventories
of wheat, and population. Data for consumer price index, exchange rate, and per capita income are based on *International Financial Statistics* [36] by the International Monetary Fund (IMF), and *Yearbook of National Account Statistics* [106] and *Statistical Yearbook* [105] by the UN. Data for production and ending inventories of wheat are taken from *Production Yearbook* [24] by the FAO, and *Foreign Agricultural Circular* [109] by the USDA, respectively. The source of population data is *Demographic Yearbook* [104] by the UN. As the price of substitutes for wheat, unit value of U.S. exports of corn is used for the DCs, Eastern Europe, and the USSR; or unit value of U.S. and Thailand exports of rice weighted by market shares is used for the LDCs and China. These data are taken from *Trade Yearbook* [25] by the FAO.

In constructing the "effective" consumer price index and the "effective" real income defined in Equations (3.31) and (3.34), respectively, only the major wheat-importing countries are considered within each market region. The list of countries considered in each region is as follows: EC-6 (West Germany, Italy, and the Netherlands), EC-3 (the United Kingdom), Japan (Japan), the rest of the DCs (Switzerland, Portugal, and Israel), NICs (Brazil, Mexico, and South Korea), OPEC (Iran, Iraq, Indonesia, Nigeria, and Venezuela), the rest of the LDCs (India, Pakistan, Egypt, Morocco, Peru, and the Philippines), China (China), Eastern Europe (Poland, East Germany, and Czechoslovakia), and the USSR (the USSR). This list is also used for collecting data of wheat inventories.
The estimation of the supply side equations requires another set of data on exporting countries. The export price of wheat is taken as unit value of total exports of wheat in each exporting country from the same data sources as for the trade flow equations. Then, the export price is converted into domestic currency terms by the exchange rate obtained in the IMF's statistics [36]. Production of wheat, the price index of variable inputs, and the price index of livestock are obtained from the FAO's Production Yearbook [24]. The price of alternative crops is defined in consideration of land use as unit value of exports of sorghum for the U.S. and Argentina or unit value of exports of barley for Canada, Australia and France; data are available in the FAO's Trade Yearbook [25]. The consumption data of wheat in exporting countries are drawn and adjusted for the calendar year from the USDA's Foreign Agriculture Circular [109]. Data for consumer price index and per capita income are taken from the same sources as for the per capita total wheat import demand equations. In order to make the analysis consistent, inventories of wheat for exporting countries are derived from production, consumption, and export data, given the initial value of inventories.

Among the variables in the supply side equations, data for the weather index is the most difficult to obtain. As an approximation, a yield variation index is constructed and used in the model for the weather index. The yield variation index is defined as a percent deviation of the actual yield from a secure time trend level of the yield. Namely, it is represented by:
where $W_{it}$ is the yield variation index of country $i$ at time $t$, $YD_{it}$ is the actual yield of country $i$ at time $t$, and $E(YD_{it})$ is the expected value of the yield of country $i$ at time $t$, which is obtained by regression of the yield on time trend. It is noted that the yield variation index has expected value of zero as requested. Data for yields are obtained from the FAO's Production Yearbook [24].

Data for the price linkage equations are all available directly from the data used in the estimations of the other equations.

Other Notes on the Estimation

Prior to the real estimation of the model for world wheat trade, several more comments must be mentioned on the estimation procedure.

First of all, the time period used in the estimation differs by equation mainly depending on the data availability. The time period for the per capita total wheat import demand equations and the supply side equations is the period 1961 (or 1962) to 1978, while the time period for the trade flow equations is the period 1964 to 1978. The first three years of the period for the trade flow equations are used as the base period. That is, data of the base period are taken in the form of a three-year average of the period 1964 to 1966, and the time series data of prices are normalized by setting all prices in the base period equal to unity in the estimation of the trade flow equations. The reason for taking a three-year average rather than taking a single
year for the base period is that the trade flows are very volatile and the estimation results are sensitive to the choice of base period; in addition, any trade flow must take non-zero value in the base period.

Definition of trade flows needs some notes. Imports of the EC-6 from France are not included in the system of trade flow equations because the EC-6 is considered as a single unit for economic activities. Instead, the domestic demand for French wheat consists of two parts: demand for wheat in France and demand for French wheat in other EC-6 member countries. Correspondingly, one more equation has to be estimated in the supply side equations for France; the per capita demand equation for French wheat in the EC-5 countries other than France. The equation is specified in the same framework as the per capita domestic demand equations:

\[
CS_{et} = d_{0e} + d_{1e} \left( \frac{PWF}{CPI_e} \right) + d_{2e} \left( \frac{PL_e}{CPI_e} \right) + d_{3e} Y_{et} + v_{et}
\]

(4.9)

where \( CS_{et} \) is the per capita demand for French wheat in the EC-5 countries, \( PWF \) is the market price of French wheat, equated to unit value of French exports to the EC-5 countries, and \( PL_e, CPI_e, \) and \( Y_e \) are the price of livestock, the consumer price index, and the per capita real income, respectively, of the EC-5 countries. The disturbance term, \( v_{et} \), has the same nature as the disturbance terms in the supply side equations discussed previously. The total demand for French wheat in the EC-5 countries is obtained by multiplying \( CS_{et} \) by population of the EC-5 countries, \( N_{et} \). The data for this equation are obtained from
the sources mentioned in the previous section; for $CPI_e$ and $Y_e$, the "effective" consumer price index and the "effective" per capita real income, defined in Equations (3.31) and (3.34), respectively, are used. On the other hand, imports of the EC-3 from France are included in the system of trade flow equations because in reality, the Common Agricultural Policy (CAP) has been effective for these new members since only the late 1970s.

In the estimation of the trade flow equations, the following trade flows are omitted because the data of these trade flows show zero or negligible numbers in most of the time periods estimated; imports of the EC-3 from Argentina, imports of Japan from Argentina and France, and imports of the NICs from France. In addition, aggregations are made for the centrally planned economies because the number of non-zero data of the following imports is not sufficient to estimate trade flows individually; imports of China from Argentina, France and U.S., and imports of Eastern Europe and imports of the USSR from Australia, Argentina, and France are aggregated, respectively. Furthermore, if the unit value of individual imports is not available for the import price corresponding to the trade flow because of no imports in a certain year, then the average export price index of the corresponding exporting country, which is set equal to unity at the base period as well, is replaced with the individual import price index.

The UN's and the FAO's statistics combine all the data for Taiwan with the data for China since 1972. In this study, however, Taiwan is considered as one of the NICs and should be differentiated from the
mainland China. The statistics published by the IWC, the OECD, and the USDA treat Taiwan separately; therefore, the data for Taiwan are taken from these sources. Thus, even if data sources are referred to the UN's or the FAO's statistics, the data for Taiwan and China are always differentiated and adjusted, if necessary, in this study.

All the equations of the model discussed in this chapter are estimated first as originally specified. Then, the equations are respecified by deleting the variables whose coefficients are not significantly different from zero because the inclusion of irrelevant variables results in the loss of efficiency of the estimators. (See Pindyck and Rubinfeld [67].) The criterion of deleting variables is the test of each coefficient at the 10 percent significance level; only the variables whose coefficients are significantly different from zero at least at the 10 percent level are basically included in the model. However, several other variables are also kept in the model if their presence is theoretically sound and they are very important in maintaining the simultaneity of the model. Even in such a case, the variables must have the coefficients whose t-values are more than unity in absolute value. This is the second criterion. In the final estimation of the model, some dummy variables are introduced to take into account the extraordinary shifts of dependent variables, which cannot be explained by the original model specification.
CHAPTER V. ESTIMATION RESULTS

This chapter is devoted to presenting the results of the model estimations. The equations to be estimated are divided into four groups: the trade flow equations, the per capita total wheat import demand equations, the supply side equations, and the price linkage equations. The first two groups of equations are estimated by the "seemingly unrelated regressions (SUR)" technique. The rest of the equations in the latter two groups are estimated by the ordinary least squares (OLS) method or the ordinary least squares corrected for autocorrelation (ALS) method. For the estimations, annual data based on calendar year are used. In the estimation of the trade flow equations, the equations are grouped by market region, and the equation of trade flow from the U.S. in each market region is arbitrarily dropped because of the redundancy of the equations in the estimation. The coefficients of the equation of trade flow from the U.S. are calculated from other coefficients to be estimated. The per capita total wheat import demand equations are estimated together as a single set of equations to take into account the correlations among disturbance terms of the equations. All other equations are estimated separately. Definitions of the variables used in the estimations and the sources of data are listed in Appendix A.

In the following sections, the final results of the estimations are presented. First, the per capita total wheat import demand equations and the trade flow equations are reported by market region. Second, the supply side equations are reported by country, and third the results for the price linkage equations are reported. Finally, an overall
evaluation of the estimates is made with discussions on the elasticities obtained from the estimates in the last section.

Importing Regions

As presented in Table 1.3, the world is divided in this study into ten market regions: EC-6, EC-3, Japan, rest of the DCs, NICs, OPEC, rest of the LDCs, China, Eastern Europe, and the USSR. Each market region has the per capita total wheat import demand (hereafter, referred simply to as "import demand") equation and the trade flow equations. The equations are estimated by the SUR technique; therefore, mean square error and \( R^2 \) are not reported for each equation. Instead, weighted mean square error and weighted \( R^2 \) are reported for the system. The import demand equations are estimated for all the regions together as a single system for the period of 1962-1978. The estimation gives the following statistics for the system of import demand equations:

- Weighted mean square error for system = 1.142
- Weighted \( R^2 \) for system = 0.98.

The estimated coefficients and t-statistics (in parentheses) of the demand equations are reported by region, followed by the trade flow equations which include the estimated coefficients, t-statistics, and weighted mean square error (W.MSE) and weighted \( R^2 \) (W.R\(^2\)) for the system. The trade flow equation for imports from the U.S. is reported with only the coefficients which are derived from other estimated coefficients.

For the references, the OLS estimates of the import demand equations obtained in the first stage of the SUR procedure are reported
in Appendix B.

To represent the exporting countries and the importing regions, the following code is used:

**Exporting country = I;**

1 = Argentina, 2 = Australia, 3 = Canada, 4 = France, and 5 = U.S.

**Importing Region = J;**

1 = EC-6, 2 = EC-3, 3 = Japan, 4 = rest of DCs, 5 = NICs, 6 = OPEC, 7 = rest of LDCs, 8 = China, 9 = Eastern Europe, and 10 = USSR.

**EC-6 (Region 1)**

**Import demand:** SUR (1962-1978)

\[
MQ1 = 22.123 - 8.8154*\left(\frac{P1}{CPE1}\right) + 0.2464*\left(\frac{P1}{CPE1}\right) - 4.2597*YE1
\]

\[
(4.96) \quad (-3.89) \quad (2.85) \quad (-3.13)
\]

**Trade flows:** SUR (1964-1978)

\[
X11 = S11*M1 - 66.018*T + 30.021*TD
\]

\[
(-4.66) \quad (1.94)
\]

\[
X21 = S21*M1 + 28.316*T - 297.03*TD
\]

\[
(2.74) \quad (-2.76)
\]

\[
X31 = S31*M1 - 215.99*TD
\]

\[
(-2.21)
\]

\[
X51 = S51*M1 + 37.702*T - 30.021*TD + 513.02*TD
\]

**For system:** W.\text{MSE} = 1.143 \quad W.R^2 = 0.69
The import demand of the EC-6 is explained by the real import prices of wheat and corn and real income. However, the allocation of the demand to individual suppliers does not depend on the prices; the time trend and the dummy variable to show the shift of preference are dominant in the market share determination.

The EC has the variable levies to protect its common pricing system for grains by raising prices of imported wheat to equal the threshold or minimum import price. The same levy is applied to all grades and qualities of wheat without regard to origin. The EC, therefore, would be expected to seek to minimize import costs and simultaneously maximize variable levy income on a fixed quantity of imports. (See McCalla [59].) This dual objective would lead the EC to seek the lowest possible offer price in the international market. The estimation results, however, show a conflict with this hypothesis. The EC shows some degree of response to price in the import demand for total wheat, but no response to price in allocating it to suppliers. It is very difficult to analyze the market behavior of the EC because of the complexity of its policies. Additionally, data used in this study are annual data and the prices are approximated by unit values based on the FOB export prices. Therefore, the estimations in this study may not be appropriate to test correctly the hypothesis of the EC's responses to price change.

In the preliminary estimations, the threshold price of wheat for the import price is introduced in the import demand equation. However, the result was very poor. One of the reasons for this poor result is that the Common Agricultural Policy (CAP) for grains was not fully
implemented until 1967-68; therefore, the pure effects of the CAP do not show up in the estimation.

When the above estimation results are referred to, or used in other analysis, the role of the CAP must always be kept in mind. The details of the CAP are discussed in Fennell [22]. (See also Jabara and Brigida [41], and USDA [108].)

**EC-3 (Region 2)**

Import demand: SUR (1962-1978)

\[
MQ2 = 95.290 - 51.674*(\frac{P_2}{CPE2}) + 1.0794*(\frac{PA2}{CPE2}) - 13.760*YE2 - 1.1457*SP2
\]

\[
(5.53) \quad (-4.54) \quad (3.28) \quad (-2.12) \quad (-2.29)
\]

Trade flows: SUR (1964-1978)

\[
X_{22} = S_{22}M_2 - 0.7538B_{22}(P_{22} - P_2) + 47.926*T - 943.37*D
\]

\[
(-2.48) \quad (2.02) \quad (-3.84)
\]

\[
X_{32} = S_{32}M_2 - 0.7538B_{32}(P_{32} - P_2) - 126.47*T + 914.06*D
\]

\[
(-2.48) \quad (-6.53) \quad (4.63)
\]

\[
X_{42} = S_{42}M_2 - 0.7538B_{42}(P_{42} - P_2) + 96.739*T
\]

\[
(-2.60) \quad (6.89)
\]

\[
X_{52} = S_{52}M_2 - 0.7538B_{52}(P_{52} - P_2) - 18.195*T + 29.31*D
\]

For system; \( W_{MSE} = 1.140 \quad W_{R^2} = 0.77 \)

The EC-3 countries, the United Kingdom, Denmark, and Ireland, which acceded to the EC in 1973, were weakly regulated by the CAP during
the estimation period because even after joining the EC, the period 1973 to 1977 was considered as the transition period. Therefore, the estimation results show different market behavior of the EC-3 from the original EC-6. Relatively large price coefficients of the import demand equation are noted.

In the trade flow equations, the coefficient for the elasticity of substitution is -0.7538 showing a price mechanism in the market share determination. The coefficients of the time trend show changes in the preference over time mainly from Canada to France; other things being equal, Canada lost annually 126 thousand metric tons of wheat exports and France gained annually 97 thousand metric tons of wheat exports in this market. On the other hand, the dummy coefficients show the shift of the preference parameter from Australia to Canada in 1973; about 900 thousand metric tons of wheat exports were shifted from the former to the latter. Among the EC-3 countries, the United Kingdom is the dominant country and the estimated results correspond to the behavior of the U.K.

Although the estimation results show relatively large demand responses of the EC-3 to price changes, the EC-3 is not expected to keep these demand responses in the future period. The EC's Common Agricultural Policy regulates the EC-3 as well as other original members; therefore, the EC-3 tends to behave in the same manner as the EC-6. In order to analyze the behavior of the EC-3 as a member of the EC, more data are required.
Japan (Region 3)

Import demand: SUR (1962-1978)

\[ MQ3 = 33.556 - 2.3494^{(P3)}_{CP3} + 12.956^{(YE3)} - 0.5563^{(Q3)} \]
\[ (5.47) \quad (-1.00) \quad (3.84) \quad (-3.01) \]

Trade flows: SUR (1964-1978)

\[ X23 = S23^{(M3)} + 128.78^{(T)} - 953.25^{(D)} \]
\[ (6.30) \quad (-4.49) \]

\[ X33 = S33^{(M3)} - 120.35^{(T)} + 51.917^{(TD)} \]
\[ (-13.42) \quad (5.38) \]

\[ X53 = S53^{(M3)} - 8.43^{(AT)} - 51.917^{(TD)} + 953.25^{(D)} \]

For system: \[ W,MSE = 1.182 \quad W,R^2 = 0.96 \]

Wheat is used mostly for human consumption in Japan. Japan's import demand is explained by the import price, income, and domestic production. However, the coefficient of price variable is very small compared with the quantity of imports. This means that Japan's response to price change is inelastic. The income coefficient is positive and it shows that wheat was not an inferior good in Japan during the estimation period. The production coefficient shows that other things being equal, each ton reduction of domestic production increased wheat imports by more than a half ton.

The trade flow equations, which show no response to price change, explain the structure of preference change over time. The basic preference shifted toward the U.S. at the cost of Australia in 1973, but
a secure trend favoring Australia is observed. Canada has lost its share over time, although the pace of losing was slowed down since 1973. Japan's wheat imports are under complete government control. The quantity of imports is determined by the government and wheat can only be imported under a government administered quota system. The licenses are issued by the Japanese Food Agency and all wheat imported must be sold to the government at the port. Therefore, Japan is also expected to seek to buy the quantity of wheat determined by the government at lower prices. However, according to the estimated trade flow equation, Japan seems to depend on only the nonprice factors in the determination of suppliers.

Japan is the single largest importer except the centrally planned economies; Japan's imports have continuously increased, whereas domestic wheat production has declined. As a result, Japan's self-sufficiency ratio of wheat has been reduced to about 5 percent. Therefore, the reliability and continuity of supply are the important factors in the determination of suppliers of wheat imports. In addition, Japan tends to diversify the purchases to minimize the probability of restricted supply. Indeed, the Japanese government has entered into trade arrangements with the United States, Canada, and Australia on a bilateral basis since 1972. The arrangements generally specify the quantities of wheat to be imported for a year. These factors seem to be reflected in the estimated trade flow equations.
Rest of DCs (Region 4)

Import demand: SUR (1962-1978)

\[ MQ4 = 27.069 - 17.576*(P4_{CPE4}) + 0.5133*(P4_{CPE4}) - 11.902*YE4 \]
\[ (1.75) \quad (-2.54) \quad (2.15) \quad (-2.11) \]

Trade flows: SUR (1964-1978)

\[ X14 = S14*M4 - 0.4768*B14*(P14 - P4) - 25.874*T + 23.969*TD \]
\[ (-5.73) \quad (-5.60) \quad (5.03) \]

\[ X24 = S24*M4 - 0.4768*B24*(P24 - P4) - 10.507*T \]
\[ (-6.01) \quad (-3.40) \]

\[ X34 = S34*M4 - 0.4768*B34*(P34 - P4) - 32.200*T + 323.46*0 \]
\[ (-5.73) \quad (-4.63) \quad (4.68) \]

\[ X44 = S44*M4 - 0.4768*B44*(P44 - P4) - 18.597*T + 18.513*TD \]
\[ (-5.73) \quad (-3.15) \quad (2.98) \]

\[ X54 = S54*M4 - 0.4768*B54*(P54 - P4) + 87.178*T - 42.482*TD \]
\[ - 323.46*D \]

For system: \( W,MSE = 1.350 \quad W,R^2 = 0.73 \)

The import demand of the rest of the DCs is explained mainly by the consumption demand factors; wheat and corn prices and income. The coefficient of income shows a relatively large negative number compared with the size of imports. It may include the effect of diet changes in these countries over time.

The trade flow equations show a certain price effect on the choice of suppliers of imports. The coefficient for the elasticity of substitution is -0.4768 with large t-value. The coefficients for
preference changes indicate that the preference changes favored the U.S. at the cost of all other exporters until 1972, but thereafter, the preference remained the same for Argentina and France and the changes occurred mainly between the U.S. and Canada; the sum of the coefficients of T and TD is very small for Argentina and France, while the U.S. and Canada have relatively large coefficients of the time trend.

Major importers in this region are Switzerland, Portugal, and Israel, although none of them has ever exceeded one million tons of wheat imports. The importance of this region has declined in the world market and most of the countries in this region are nearly self-sufficient in wheat. It is noted that among the countries in this region, Greece joined the EC on January 1, 1981, and Spain and Portugal also are supposed to join the EC in the next few years; therefore, the market behavior of this region would be different in the future from what the estimations in this study describe.

**NICs (Region 5)**

**Import demand: SUR (1962-1978)**

\[ MQ5 = 26.836 - 14.935*(\frac{P5}{CPE5}) + 0.04903*(\frac{P5}{CPE5}) + 44.008*YE5 \]

\[ \text{ (8.11) (2.41) (7.77) } \]

\[ - 3.8684*ST5 - 0.6290*A5 \]

\[ \text{ (-7.83) (-4.55) } \]

**Trade flows: SUR (1964-1978)**

\[ X15 = S15*M5 - 257.271*T \]

\[ \text{ (-13.11) } \]
The NICs increased the commercial imports of wheat very rapidly during the estimation period. The import demand of this group is explained by all the variables in the theoretical model except production. All the coefficients have correct sign and are significantly different from zero. The coefficient of the PL 480 imports is -0.6290; less than unity in absolute value. This means that the PL 480 imports, which have declined substantially, are not completely substituted by commercial imports. Among the countries in this group, Brazil and South Korea were large recipient countries of the PL 480 shipments, although all wheat imports in Brazil have been commercial since 1971.

In contrast to the import demand equation, the trade flow equations show no price effect on the market share determination. The coefficients indicate that the time trend favors the U.S. against Argentina and that the shift of preference occurred from Australia to the U.S. in 1973. These changes correspond to increases in commercial imports from the U.S. substituting for the PL 480 shipments.

The two dominant importers in this group, Brazil and South Korea, are importing wheat under government control. In Brazil, the Wheat Marketing Office of the Bank of Brazil holds sole authority for purchase.
and resale of all imported wheat, and in South Korea, the Korean Flour Mills Industry Association is the sole importer of wheat, recognized by the government. Determination of the quantity to be imported is flexible in both countries depending on the demand and supply situation (Jabara [40]).

This group of importing countries is characterized by rapid economic growth and foreign exchange availability based on exports. Their rising income has enabled them to import wheat on a commercial basis. However, one may anticipate that further income growth changes their diet pattern to consume more meat; therefore, the growth rate of wheat imports may slow down.

**OPEC (Region 6)**

**Import demand: SUR (1962-1978)**

\[
MQ_6 = 9.083 - 4.6173 \cdot \frac{P_6}{GPE_6} + 35.408 \cdot YE_6 - 1.7311 \cdot ST_6 - 0.3116 \cdot Q_6
\]

\[
(2.63) \quad (-2.26) \quad (9.23) \quad (-3.71) \quad (-3.53)
\]

**Trade flows: SUR (1964-1978)**

\[
X_{16} = S_{16} \cdot M_6 - 0.6075 \cdot B_{16} \cdot (P_{16} - P_6) + 84.574 \cdot D
\]

\[
(-2.78) \quad (1.90)
\]

\[
X_{26} = S_{26} \cdot M_6 - 0.6075 \cdot B_{26} \cdot (P_{26} - P_6)
\]

\[
(-2.90)
\]

\[
X_{36} = S_{36} \cdot M_6 - 0.6075 \cdot B_{36} \cdot (P_{36} - P_6) - 42.293 \cdot T
\]

\[
(-2.78) \quad (-6.17)
\]
\[ X_{46} = S_{46} \times M_{6} - 0.6075 \times B_{46} \times (P_{46} - P_{6}) - 57.605 \times T \]
\[ (-2.78) \quad (-18.20) \]

\[ X_{56} = S_{56} \times M_{6} - 0.6075 \times B_{56} \times (P_{56} - P_{6}) + 99.898 \times T - 84.574 \times D \]

For system; \( W.M.S.E = 1.084 \quad W.R^2 = .92 \)

OPEC is the most rapidly growing market in the world. Their imports spurted in the 1970s as the rapid increases in oil prices brought sufficient foreign exchange and rapid growth of per capita income. The wheat import demand of OPEC depends on the import price, income, and the domestic supply factors of inventories and production. Note the large income coefficient. In the preliminary estimations, the variable of PL 480 shipments was introduced, but the estimated coefficient was not significantly different from zero.

The trade flow equations show the market share response to price changes. The coefficient for the elasticity of substitution is -0.6075. The preference changes are relatively simple to interpret; the taste of OPEC is changing toward the U.S. against Canada and France, although a small shift from the U.S. to Argentina took place in 1973.

The countries in this group are also expected to shift their diet pattern to consume more meat; one may anticipate that food grain demand could soon become saturated. However, their economies largely depend on the oil prices as the main source of foreign exchange. Therefore, the import demand of this group is not free from the world energy situation.
Rest of LDCs (Region 7)

Import demand: SUR (1962-1978)

\[ \text{MQ7} = -13.931 + 175.02 \times \text{YE7} - 0.4801 \times \text{ST7} - 0.1625 \times \text{Q7} - 0.5297 \times \text{A7} \]

Trade flows: SUR (1964-1978)

\[ \text{X17} = \text{S17} \times \text{M7} - 2.1214 \times \text{B17} \times (\text{P17} - \text{P7}) - 96.261 \times \text{T} + 2462.98 \times \text{D} \]

\[ \text{X27} = \text{S27} \times \text{M7} - 2.1214 \times \text{B27} \times (\text{P27} - \text{P7}) + 235.038 \times \text{T} - 2462.98 \times \text{D} \]

\[ \text{X37} = \text{S37} \times \text{M7} - 2.1214 \times \text{B37} \times (\text{P37} - \text{P7}) - 1374.83 \times \text{D} \]

\[ \text{X47} = \text{S47} \times \text{M7} - 2.1214 \times \text{B47} \times (\text{P47} - \text{P7}) + 454.58 \times \text{D} \]

\[ \text{X57} = \text{S57} \times \text{M7} - 2.1214 \times \text{B57} \times (\text{P57} - \text{P7}) - 138.777 \times \text{T} + 3383.23 \times \text{D} \]

For system; \( \text{W.MSE} = 1.768 \quad \text{W.R}^2 = .71 \)

The rest of the LDCs is now the dominant importer of wheat in the world market. This group is characterized by poverty and extreme limitations on foreign exchange. The import demand of this group is determined by only nonprice factors; the price coefficients were not significantly different from zero in the preliminary estimations. The import demand is explained by income, inventories, production, and the PL 480 imports. The rapid increases in commercial imports result in the
large coefficient of income variable. The coefficient of the PL 480 imports shows that other things being equal, each ton decrease in PL 480 wheat increased the commercial sales by about a half ton of wheat.

The insensitivity of the import demand to price means that the quantity of imports is determined by some necessities caused by noneconomic reasons as well as income and domestic supply factors. Furthermore, the existence of policies of low urban food prices tend to force wheat imports regardless of price. However, once the quantity to be imported is determined, as the estimated trade flow equations show, they seek to buy that quantity at lower prices. The large value of the coefficient of the elasticity of substitution must be noted; it takes a value of \(-2.1214\); much greater than any other estimates of the elasticity of substitution. This elastic substitutability among suppliers means the large response of this group to price to buy the necessary quantity of wheat seeking lower possible offer prices in the international market. Such behavior helps to save foreign exchange that is definitely scarce in the countries in this group.

The trade flow equations indicate the preference changes as well. The market share change tends to favor Australia at the cost of Argentina and the U.S., although Australia and Canada experienced a downward shift of the share in 1973; the U.S. gained from a large upward shift of the share in 1973, and France gained a little from an increase in the share in 1973.
The importance of the countries in this group will remain or even increase further in the world market because they still have a lot of potential demand for food grains. Their import demand perspective typically depends on domestic production, income, and population growth. The countries in this group have struggled in the race between rapidly growing populations, rising incomes and expectations, and less rapidly growing and unstable production. Government policy is also one of the key factors influencing the import demand.

China (Region 8)

Import demand: SUR (1962-1978)

\[
MQ_8 = 12.012 - 3.5886*P_8 + 0.0230*PA_8 - 0.1458*Q_8 + 3.7291*D_8
\]

\[(7.01)\quad (-3.80)\quad (4.72)\quad (-2.88)\quad (4.15)\]

Trade flows: SUR (1964-1978)

\[
X_{28} = S_{28}*M_8 + 296.51*TD - 3137.01*D
\]

\[(1.99)\quad (-2.21)\]

\[
X_{38} = S_{38}*M_8 + 232.63*T - 187.07*TD
\]

\[(6.93)\quad (-4.87)\]

\[
X_{58}^* = S_{58}*M_8 - 232.63*T - 109.44*TD + 3137.01*D
\]

For system; W.MSE = 1.093 \quad W.R^2 = .75

China is one of the large single importers, although its market share in the world trade is volatile. Of all the major wheat importing countries, data on China are the most limited. Data for income and internal price variables are not available. Therefore, the import demand
is regressed on nominal prices of wheat and rice, and production. A dummy variable, D8, is also introduced to take into account the sudden increases in wheat imports in 1977 and 1978, which could not be explained by the original specification of the model. The estimated import demand equation shows the demand response of China to price changes. The inclusion of the rice price variable in the equation requires an explanation. The rice price is introduced not strictly for the substitution effect in consumption, but rather for foreign exchange earnings. Despite food deficiency, China exports around one million metric tons of rice annually in order to replace it with cheaper imported wheat. (See, for example, Miles [61].) The rice price in the world market is influencing China's foreign exchange earnings, which enables China to import wheat. The world rice price, therefore, is positively correlated to the wheat imports in China as the estimated equation shows.

The estimated trade flow equations indicate no response to price in the determination of suppliers. The parameters for preference changes show that a large shift from Australia to the others (mainly to the U.S.) took place in 1973 and that the time trend, however, has favored Australia since 1973. It is noted that the trade flows from Argentina, France, and the U.S. are aggregated together and denoted by X58*; the corresponding base period share is denoted by S58*.

Eastern Europe (Region 9)

Import demand: SUR (1962-1978)

\[ MQ9 = 35.082 - 5.0761*P9 - 0.6559*A9 \]

\text{\( (7.72) \)} \quad \text{\( (-2.15) \)} \quad \text{\( (-7.63) \)}
Eastern Europe is linked closely to the USSR. The imports of wheat in Eastern Europe depended mostly on the USSR until the latter became a net importer of grain in the early 1970s. As the imports from the USSR decreased, Eastern Europe had to look outside the communist block and buy wheat on a commercial basis. The commercial import demand for wheat is explained by the import price and the imports from the USSR. It is noted that the price variable is expressed in nominal terms; the consumer price indices in the centrally planned economies are almost constant. In the preliminary estimations, an income variable based on net material product was introduced, but the estimated coefficient was not significantly different from zero.

It is interesting that the estimated trade flow equations show a sensitivity of this group to price changes in the determination of suppliers. The estimated coefficient for the elasticity of substitution, \(-0.3163\), is relatively small but significantly different from zero. The parameters for preference change show only the shift from Argentina, Australia, and France together, to the U.S. It is noted that the trade
flows from Argentina, Australia, and France are aggregated together and denoted by $X_{49}^*$; the corresponding base period share, base period imports, and import price are denoted by $S_{49}^*$, $B_{49}^*$, and $P_{49}^*$, respectively.

**USSR (Region 10)**

**Import demand: SUR (1962-1978)**

$$QM_{10} = 44.055 - 25.719^*P_{10} - 0.1003^*ST_{10} + 40.417^*D$$

$(7.40)\quad (-5.51)\quad (-3.56)\quad (6.57)$

**Trade flows: SUR (1964-1978)**

$$X_{210}^* = S_{210}^*M_{10} - 146.60^*T + 399.69^*TD - 3192.7^*D$$

$(-2.95)\quad (2.17)\quad (-1.86)$

$$X_{310} = S_{310}^*M_{10} + 434.74^*TD - 6279.9^*D$$

$(2.15)\quad (-3.22)$

$$X_{510} = S_{510}^*M_{10} + 146.60^*T - 834.43^*TD + 9472.6^*D$$

For system; $W,MSE = 1.233\quad W,R^2 = .74$

The USSR, which used to be an exporter, is now one of the largest single importers of wheat. Imports of wheat in the USSR are very volatile and the behavior of the USSR is one of the major sources of the wheat market's instability in the world. The import demand is explained by the import price, the inventory level, and the dummy variable to show a shift of the USSR's import behavior since 1973. It is noted that the price variable is expressed in nominal terms. Interpretation of the large estimated coefficient of the price variable needs consideration.
The import behavior of the USSR causes fluctuations of the export prices in the world with a time lag. The USSR's grain purchase in 1972-1973, typically, caused the world wide upsurge in wheat price in 1973-74. Data of the unit values for wheat exports show that all the exporting countries experienced much higher export prices of wheat in 1974 than in 1972 or 1973. On the other hand, the USSR had ended the grain purchase before the prices increased. This time lag of price response to the USSR's imports seems to result in the large significant coefficient of the price variable. Therefore, this estimate must be interpreted with caution.

In the preliminary estimations, domestic production and income variables were introduced, but neither of them showed significant coefficients. It was anticipated that the unstable domestic production was correlated to the imports in the USSR. However, the statistical results were poor. This may depend on a time lag of the imports which are demanded to make up the shortage of domestic production. Indeed, the import demand is influenced by the lagged inventories which are strongly related to the lagged production; therefore, the import demand might be a function of the lagged production in the USSR.

The estimated trade flow equations show no price effect on the determination of suppliers. For the preference changes, an outstanding shift from all other exporters to the U.S. occurred in 1973, but the time trend favored all other exporters, especially Canada, against the U.S. since 1973. It is noted that the trade flows from Argentina, Australia, and France are aggregated together and denoted by X210*; the corresponding base year share is denoted by S210*. 
Exporting Countries

For each of the five major exporting countries of wheat, the production equation, the domestic demand equation, and the inventory equation are estimated separately using ordinary least squares (OLS) or ordinary least squares corrected for autocorrelation (ALS). Each equation includes the estimated coefficients, t-statistics (in parentheses), mean square error (MSE), Durbin-Watson d statistic (DW) or h statistic (H), the estimated autocorrelation coefficient (p) in equations adjusted for autocorrelation, and R-square ($R^2$). It is noted that the time trend variable takes the value of last two digits of the year and it is denoted by YR in this section. The country code is the same as used previously: 1 (Argentina), 2 (Australia), 3 (Canada), 4 (France), and 5 (U.S.).

For references, the created data of the yield variation index for the weather index variable in the production equation are shown in Appendix C.

Argentina (Country 1)

Production: OLS (1962-1978)

\[ PD1 = 4.4553 + 0.02387 \times (PD1)_{-1} + 0.07134 \times W1 \]

\[ (3.89) \quad (2.44) \quad (3.48) \]

MSE = 1.307   DW = 1.83   $R^2 = .68$

Consumption: OLS (1962-1978)

\[ CS1 = 203.02 - 0.4318 \times YR + 25.466 \times D70 + 35.285 \times D76 \]

\[ (7.87) \quad (-1.17) \quad (3.47) \quad (4.57) \]
MSE = 50.57  DW = 2.11  \( R^2 = .70 \)

Inventories: OLS (1962-1978)

\[
\text{IN}_1 = -4.9093 + 1.0603*\text{PD}_1 + 0.3105*\text{IN}_{1-1} \\
(-9.94) \quad (17.37) \quad (5.77)
\]

MSE = 0.212  \( H = -0.285 \quad R^2 = .96 \)

Wheat exports of Argentina are unstable and their market share has fluctuated over time. The instability of Argentina's exports comes mainly from unstable production. Additionally, political unrest in Argentina also has helped the instability of their exports. Wheat production is explained by the export price and the yield variation index for weather changes. There are no data available for the variable input prices in Argentina. Therefore, the consumer price index is used for the denominator of the export price as an approximation.

Per capita consumption of wheat in Argentina cannot be explained by any economic variables; it is explained by time trend and two dummy variables to take into account extraordinary high consumption level in 1970 and 1976. In the preliminary estimations, the cattle price and income were introduced, but neither showed significant results. One of the reasons for the insensitivity of income to consumption is the difficulty of estimating real income due to the very rapidly increasing inflation rate during the 1970s. Recurrent civil strife and changing government policies might have affected consumers' behavior as noneconomic factors.
The inventory level is explained by production and the lagged inventories. In Argentina, wheat is harvested in November, December, and January. Therefore, the inventories level at the end of the calendar year is strongly related to the level of production. The price coefficient introduced into the inventory equation in the preliminary estimations was not significantly different from zero.

Argentina operated wheat exports under complete control by the National Grain Board from 1974 to 1976. Since that period, the authority of the Board has been regulatory in nature and trade in wheat has been open to private grain traders. Exporters are required to register their sales with the Board. In the preliminary estimations for Argentina, however, any clear effect of the Board did not show up by introducing a policy dummy variable.

**Australia (Country 2)**

Production: ALS (1961-1978)

$$PD2 = -12.411 + 0.1165*W2 + 0.3305*YR - 2.1057*G2$$

\begin{align*}
(-1.95) & \quad (9.87) & \quad (3.62) & \quad (-2.30)
\end{align*}

MSE = 1.300 \quad \rho = -.5159 \quad R^2 = .91

Consumption: OLS (1961-1978)

$$CS2 = 556.94 - 5.2919*(\frac{HCP}{CPI2}) + 60.420*(\frac{PL2}{CPI2}) - 64.172*Y2$$

\begin{align*}
(5.57) & \quad (-4.46) & \quad (2.72) & \quad (-2.55)
\end{align*}

-59.528*D78

\begin{align*}
(-3.10)
\end{align*}
Australia's wheat exports have generally ranked third in world trade behind the U.S. and Canada. However, the importance of Australia in the world market has recently increased, and Australian wheat exports exceeded Canadian exports in 1979-80 (July/June) for the first time. On the other hand, wheat production in Australia is unstable and it leads to the fluctuation of Australia's market share. Australia has a wheat marketing board, called the Australian Wheat Board (AWB), which has the sole authority throughout the country for buying, handling, and selling of wheat. The role of the AWB is discussed in detail, for example, in Richards [70].

Production of wheat in Australia is explained by weather changes represented by the yield variation index, time trend to show a secure change in technology, and a dummy variable for the government policy of delivery quotas for wheat. The domestic prices of wheat are set independently of the world market because the AWB has virtually complete control over domestic supplies; therefore, the export price variable did not influence production in the preliminary estimations. The variable of payments to wheat growers by the AWB was also tried in the estimation to explain the production level, but the result was poor. Because of the
special arrangements for marketing wheat in Australia, the return to wheat growers is based on several factors, and it is made in a series of payments spaced over a 2- to 4-year period. Therefore, it is difficult to isolate a single supply inducing price (Spriggs [91]).

The policy variable used in the estimation of production is wheat quotas, which were introduced to help ease the severe grain storage and marketing problems in the late 1960s. Wheat quotas were announced for the 1969/70 crop and continued until the 1975/76 crop. The quotas were imposed on deliveries to the AWB and not on planting acreage. As discussed by Spriggs [91], the quotas were actually effective in holding down wheat area in most of the States only for the 1970/71 crop to the 1972/73 crop. Therefore, the policy dummy variable, \( G_2 \), is equated to 1 for the years 1970 to 1972 and 0 otherwise to take into account the real effects of the wheat quotas.

Consumption of wheat in Australia is also insulated from the world market. The domestic price of wheat for consumers is determined by the government. It is called the home consumption price (HCP), and the price level is based on an assessed cost of production. Thus, the price variable for consumption equation of Australia is replaced by the home consumption price. Other variables in the consumption equation are the real price index of cattle and sheep, real per capita income and a dummy variable for an extraordinary decrease in wheat consumption in 1978. All these variables have significant effects on the level of consumption. It is noted that the wheat price coefficient is relatively large and that the income coefficient is negative. The decrease in consumption in 1978
depended mostly on decrease in feed use, but it was not explicitly explained.

The estimated inventory equation shows that the AWB's behavior is related to the world market only through the operation of inventories; the export price has a negative significant coefficient. Inventories are strongly related to the level of production as expected because wheat harvested by the end of year directly influences inventories.

Canada (Country 3)

Production: OLS (1961-1978)

\[ PD3 = -3.6645 + 0.05362*\left(\frac{PW3}{PD3}\right) - 1 + 0.1722*W3 + 0.2460*YR \]
\[ (-0.54) \quad (1.49) \quad (-1) \quad (5.54) \quad (2.72) \]

\[ -9.0112*G3 \]
\[ (-4.30) \]

\[ MSE = 3.961 \quad DW = 1.33 \quad R^2 = .82 \]

Consumption: OLS (1962-1978)

\[ CS3 = 220.57 - 0.2132*\left(\frac{PW3}{CPI3}\right) + 2.4417*Y3 \]
\[ (52.18) \quad (-5.94) \quad (2.03) \]

\[ MSE = 8.051 \quad DW = 2.39 \quad R^2 = .73 \]

Inventories: OLS (1961-1978)

\[ IN3 = -10.600 + 0.8212*PD3 + 0.8686*IN3 \]
\[ (-3.63) \quad (5.90) \quad (10.11) \]

\[ MSE = 5.559 \quad H = 1.559 \quad R^2 = .89 \]
Canada is the second largest wheat-exporting country. Until the mid-1950s, Canada was the major exporter of wheat in the world. However, Canada's market share has gradually decreased during the last two decades. Like Australia, Canada has a wheat marketing board; the Canadian Wheat Board (CWB) is the sole marketing agency for wheat exports and it is also the major domestic marketing agency for wheat. It is charged with the task of selling wheat at the best possible price while at the same time regulating producers' access to the marketplace on an equitable basis. The CWB pays producers a guaranteed minimum price, called the initial producer payment, on delivery of the grain. After all grains are marketed and CWB's expenses are deducted, the proceeds are distributed to producers as the final payment based on the amount of grain delivered. (For further discussion on the CWB, see Schmitz and McCalla [84], Meilke [60], or Oleson [65].)

Wheat production in Canada is explained by the price ratio of wheat to inputs, weather changes represented by the yield variation, time trend, and a government policy variable for the operation of LIFT (Lower Inventory For Tomorrow) in the 1970/71 crop year. The coefficient of the price variable indicates some degree of producers' response to the export price, although the coefficient is not very significant. In the preliminary estimations, the relative price of barley to wheat was also introduced, but the estimated coefficient was not significantly different from zero. The LIFT program was enacted as a one-year program for the 1970/71 crop year. It was designed to sharply reduce wheat acreage and inventories by paying farmers to put land into summer fallow.
In 1970/71, wheat acreage fell by half and ending stocks for that year were down 40 percent from the year before. Therefore, the policy dummy variable, G3, is set at 1 for 1970 and 0 otherwise. The coefficient of the dummy variable shows that other things being equal, the LIFT program decreased wheat production by 9 million tons in that year.

Consumption of wheat in Canada is explained by only the real price of wheat and real per capita income. Inclusion of the livestock price variable was not successful. To find a clear linkage of wheat demand to livestock sector, the separation of wheat demand for feed use from wheat demand for human consumption is desired. The estimated coefficients of the price and income variables are small, but significantly different from zero.

Inventories in Canada are related to production and lagged inventories; the level of inventories was not sensitive to the export price introduced in preliminary works. Wheat is carried over in either private or CWB inventories. Private inventory demand may depend on the price level for speculation, but the CWB is not considered as a speculator. Therefore, the aggregated price effects might be small and failed to show up in this study.

**France (Country 4)**

Production: OLS (1961-1978)

\[
PD4 = -17.983 + 0.004544 \times \left( \frac{PW4}{PC4} \right)_1 + 0.1728 \times W4 + 0.4534 \times YR \\
(-7.93) \quad (2.06) \quad (10.91) \quad (15.84)
\]

\[
MSE = 0.378 \quad DW = 1.74 \quad R^2 = .96
\]
Consumption: OLS (1961-1978)

\[ CS4 = 108.62 + 117.95 \times \frac{PL4}{P14} - 3.0261 \times Y4 + 21.300 \times D78 \]
\[ (2.13) \quad (2.55) \quad (-2.82) \quad (2.28) \]

\[ \text{MSE} = 61.593 \quad DW = 1.28 \quad R^2 = .66 \]

Exports to EC-5: OLS (1961-1978)

\[ CSE = -18.381 - 0.09915 \times \frac{PWF}{CPE1} + 23.300 \times YE1 + 8.5962 \times D69 \]
\[ (-1.92) \quad (-1.42) \quad (8.25) \quad (2.61) \]

\[ \text{MSE} = 10.243 \quad DW = 2.12 \quad R^2 = .90 \]

Inventories: OLS (1961-1978)

\[ IN4 = -8.8649 + 0.7326 \times PD4 + 0.7531 \times IN4 -1 \]

\[ \text{MSE} = 0.971 \quad H = 0.942 \quad R^2 = .97 \]

France is a relatively new exporting country; it has been in the export market only since the mid-1950s. However, France has grown the most rapidly among the exporters as supported by the EC's Common Agricultural Policy (CAP). French exports, in fact, have occasionally surpassed exports of Argentina or Australia. To the rapid growth of French exports, the system of export subsidies operated by the EC has largely contributed. Grain prices within the EC have traditionally exceeded world prices due to higher cost of production and the use of prices as an income policy. In order for EC grains to become internationally competitive, per ton export subsidies are introduced and they have allowed France to become increasingly important as a wheat
The elaborate price support system has resulted in steady expansion in French wheat production. The estimated equation shows a strong relationship of production with the time trend and the yield variation index for weather changes. The equation also indicates some degree of producers' response to the relative price of wheat to barley, but the coefficient is small; it implies an effect of the insulating policy.

Domestic consumption in France is explained by the real price index of livestock and products, real income, and a dummy variable for an extraordinary increase in wheat consumption in 1978. Wheat consumption in France is not well related to the real wheat price, but it is rather related directly to the livestock market. Wheat demand for human consumption in France has steadily decreased; the decrease is represented in the negative coefficient of the real income variable.

As another factor of disappearance, wheat exports to the other five EC countries must be considered because EC-6's imports from France were excluded in the import demand analysis. The consumption of French wheat in the EC-5 countries, denoted by CSE, is explained by the real price of French wheat, real income, and a dummy variable for a distinguished increase in imports from France in 1969. The price of French wheat, denoted by PWF, is approximated by the unit value of wheat exports by France to these countries. It is noted that the large coefficient of the real income variable may include the trend of consumption in these countries toward French wheat beyond the price and income effects.
The inventory level of wheat is determined by production and lagged inventories. There is no effect of export price changes on holding inventories because of the EC's insulating policy from the world market.

**United States (Country 5)**

Production: OLS (1961-1978)

\[
P_D5 = -70.580 + 0.2290*\left(\frac{PW5}{PPI5}\right) - 1 + 1.4113*YR
\]

\[
\begin{align*}
&(-8.90) \quad (4.84) \quad (12.59) \\
&MSE = 5.943 \quad DW = 2.05 \quad R^2 = .93
\end{align*}
\]

Consumption: OLS (1961-1978)

\[
C_S5 = 64.418 - 0.2968*\left(\frac{PW5}{CPI5}\right) + 12.796*\left(\frac{PL5}{CPI5}\right) + 11.168*Y5
\]

\[
\begin{align*}
&(6.30) \quad (-5.37) \quad (1.19) \quad (4.72) \\
&MSE = 13.543 \quad DW = 1.45 \quad R^2 = .80
\end{align*}
\]

Inventories: OLS (1961-1978)

\[
I_N5 = -19.398 - 0.04407*PW5 + 0.7533*PD5 + 0.7880*I_N5 - 1
\]

\[
\begin{align*}
&(-4.06) \quad (-1.25) \quad (4.40) \quad (9.21) \\
&- 14.073*\left(\frac{P73}{CPI5}\right)
\end{align*}
\]

\[
\begin{align*}
&MSE = 11.870 \quad H = 0.678 \quad R^2 = .95
\end{align*}
\]

The United States is the largest wheat-exporting country. U.S. production of wheat has ranked behind the USSR, but it exports a large percentage of production and maintains a large carryover. Therefore, the U.S. plays a leading role in the world market. Furthermore, the U.S.
is especially important in wheat trade because it is the only country which provides a reliable supply of all the important classes of wheat. The marketing of wheat in the U.S. has been left mostly in the hands of private traders; producers market their wheat through their cooperatives or through private companies. However, the U.S. government, explicitly or implicitly, influences wheat exports through policies; for example, acreage restrictions, reserve programs, and export subsidies in domestic policy, or food aid, grain embargoes, and long-term sales agreements with other countries in foreign policy. A comprehensive survey on the U.S. wheat industry, including a policy review, is given by Heid [30]. (See also Hadwiger [29] and Reitz [68].)

Production of U.S. wheat is explained only by the relative price of wheat to inputs and the time trend. The yield variation index and the relative price of sorghum to wheat, which were originally introduced, are not effective on production. In reality, there are more factors influencing wheat production. Above all, a series of government commodity programs may affect producers' decision-making; guaranteed minimum prices on production, input subsidies, payments for removing land from production, and government guidelines for planting as a prerequisite for access to payments are common forms of the policies affecting production decision-making. However, these factors complicate the analysis and it is difficult to introduce them directly into the production equation.

Domestic wheat demand contains both effects of human consumption demand and livestock feed demand. The coefficient of the real wheat
price and its relatively large t-value show a certain response of consumers and feeders to price change. It is noted that the coefficient of real income includes indirectly the effects of raised income on the consumption of meat and dairy products as well.

The estimated inventory equation shows some degree of the price effect on holding inventories, although t-value of the price coefficient is relatively low. As well as production and lagged inventories, the equation includes a dummy variable to explain an extraordinary inventory decrease in 1973, in which a great amount of wheat was shipped to Russia. As discussed previously, this Russian purchase was carried out without simultaneous upsurge of the world prices. The world market experienced the sharp increase in grain prices with a time lag. The coefficient of the dummy variable indicates that the extraordinary exports in 1973 caused a decrease in wheat inventories by 14 million tons, other things being equal. The details of the Russian grain purchase in 1972-1973 are discussed by Trager [101] and Morgan [63].

Price Linkage Equations

The final group of equations to be estimated is a set of the price linkage equations, which connect the export prices with the individual import prices. Each individual import price is regressed on the export price of the country of origin of the imports. Therefore, if the estimated coefficient is unity and the intercept is zero, then the import price is equivalent to the export price of the country of origin; no price discrimination against the importing region. The OLS or ALS method
was applied to all the 39 trade flows which were considered in the import demand analysis. All of the estimated coefficients are significantly different from zero with very large t-values. For several equations, a dummy variable was introduced to eliminate the effect of an extraordinary disturbance. Most of such extraordinary deviations from the regression lines seem to come from errors in data. Especially, if the amount of imports is very small, the calculated unit value is very sensitive to errors in data of quantity and/or value.

For convenience sake, only the estimated coefficients of the price variable are listed in Table 5.1. The full results are reported in Appendix D. Table 5.1 shows tendencies of price formation from the exporters' viewpoint. The coefficient of the export price variable implies sensitivity of the individual export price distinguished by importing region to the general export price of a given exporting country. The export prices to the developed countries are more sensitive, having the coefficients of more than unity, except the export prices of Australia to the EC-6 and the EC-3, whose coefficients are less than unity. Among the less developed countries, the export prices to OPEC show similar sensitivity to those to the developed countries; all the coefficients are more than unity. The coefficients of other less developed countries are mostly less than unity, or at most, unity. The export prices to the centrally planned economies are less sensitive to the export price of the country of origin; all the coefficients are less than unity, except the export price of Canada to the USSR, whose coefficient is almost unity. Finally, a t-test is performed in each
<table>
<thead>
<tr>
<th>Dependent import price ((P_{ij}^x))</th>
<th>Independent export price ((P_{w1}/ER_1))</th>
<th>Argentina</th>
<th>Australia</th>
<th>Canada</th>
<th>France</th>
<th>U.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC-6</td>
<td></td>
<td>1.0219</td>
<td>0.8641^</td>
<td>1.1587^</td>
<td>---</td>
<td>1.1147^</td>
</tr>
<tr>
<td>EC-3</td>
<td></td>
<td>--</td>
<td>0.9885</td>
<td>1.0743^</td>
<td>1.0321</td>
<td>1.0395</td>
</tr>
<tr>
<td>Japan</td>
<td></td>
<td>--</td>
<td>1.0642</td>
<td>1.1206^</td>
<td>---</td>
<td>1.1152^</td>
</tr>
<tr>
<td>Rest of DCs</td>
<td></td>
<td>1.2018</td>
<td>1.0246</td>
<td>1.0031</td>
<td>0.9979</td>
<td>1.0213</td>
</tr>
<tr>
<td>NICs</td>
<td></td>
<td>0.9025^</td>
<td>0.9799</td>
<td>0.8985^</td>
<td>--</td>
<td>1.0485</td>
</tr>
<tr>
<td>OPEC</td>
<td></td>
<td>1.4301^</td>
<td>1.0729^</td>
<td>1.2066^</td>
<td>1.0330</td>
<td>1.0843^</td>
</tr>
<tr>
<td>Rest of LDCs</td>
<td></td>
<td>0.9484^</td>
<td>1.0014</td>
<td>0.9196^</td>
<td>0.9496^</td>
<td>0.9715</td>
</tr>
<tr>
<td>China</td>
<td></td>
<td>--</td>
<td>0.8089^</td>
<td>0.8562^</td>
<td>--</td>
<td>0.8477^</td>
</tr>
<tr>
<td>Eastern Europe</td>
<td></td>
<td>--</td>
<td>--</td>
<td>0.8450^</td>
<td>0.5721^</td>
<td>0.8298^</td>
</tr>
<tr>
<td>USSR</td>
<td></td>
<td>--</td>
<td>0.9764</td>
<td>1.0001</td>
<td>--</td>
<td>0.6856^</td>
</tr>
</tbody>
</table>

^aIndicates statistical significance at the 5% level for testing the null hypothesis that the coefficient is unity.

^bIndicates statistical significance at the 10% level for testing the null hypothesis that the coefficient is unity.

^cIndicates statistical significance at the 1% level for testing the null hypothesis that the coefficient is unity.
equation for the hypothesis that the coefficient of the export price variable is unity. Of the 39 coefficients, 22 coefficients are significantly different from unity at least at the 10 percent level. Among them, 9 coefficients are significant at the 5 percent level, and 10 coefficients are significant at the 1 percent level. The test results are also shown in Table 5.1.

Evaluation of the Estimated Coefficients

One of the main interests in this study on world wheat trade is in the estimation of the elasticity of substitution for each market region. Regardless of the different trading systems used by countries, it is expected for each importer to seek lower offer prices of wheat in the world market to satisfy the total demand for wheat, which is predetermined, unless wheat is perfectly differentiated by country of origin. However, the estimated elasticities of substitution showed very limited response of importing regions to relative prices in the determination of suppliers, except the rest of the LDCs which was the only region having the elasticity of more than unity. Of the ten market regions, only five regions had the statistically significant coefficients for the elasticity of substitution at least at the 10 percent level. In the developed countries, the estimated elasticities were 0.7538 for the EC-3, and 0.4768 for the rest of the DCs; the estimates for the EC-6 and Japan were not significant. In the less developed countries, the elasticities were 0.6075 for OPEC and 2.1214 for the rest of the LDCs; the estimate for the NICs was not significant. In the centrally planned
economies, only Eastern Europe had a significant value of the elasticity which was 0.3163; the estimates for China and the USSR were not significant. It is noted that all the elasticities except that for the rest of the LDCs were less than unity. The value of less than unity for the elasticity means that decreases in quantity share against rises in price are not enough to decrease its value share. Therefore, the market share of a given country whose price goes up may increase in value term despite decreasing in quantity term. All of the estimated elasticities were much less than the judgmental value of the elasticity of substitution which was used in the study by Grennes et al. [28]; they assumed an elasticity of 3 among all pairs of suppliers in all markets. One of the reasons for the poor predictability, which is discussed in Sarris [78], is very likely to be their assumption of the large value for the elasticity of substitution.

In order to give validity to the model originated by Armington, the equality of the elasticity of substitution between all pairs of exporters must be tested for each market region. This equality hypothesis of the elasticity of substitution was tested for all ten market regions, using the OLS estimates obtained in the first stage of the SUR procedure. The equality was rejected in the rest of the LDCs, China, and Eastern Europe at the 5 percent level of significance. Therefore, the Armington approach may not be appropriate for these market regions.

The per capita total wheat import demand equations (the import demand equations) showed that most of the market regions had some demand response to import price. Of the ten regions, eight regions had statistically
significant coefficient of the wheat import price variable at the 5 percent level. Unlike the trade flow determination, the rest of the LDCs did not show import demand response to any prices; its total imports were determined by domestic production, inventory level, real income, and the concessional imports (by PL 480). Another region whose price response was not significant was Japan; the estimated coefficient was very small compared with the quantity of imports. However, it had negative sign and t-value of more than unity, and Japan's behavior is important for the price formation in the world market. Therefore, the price variable remained in the equation for Japan.

The calculated price and income elasticities at mean value are summarized in Table 5.2 for the import demand equations. Evaluating in absolute value, the price elasticities of the EC-3 and the rest of the DCs are about unity for wheat price and more than unity for feed grain price, but all other countries show the price elasticities which are less than unity, except the USSR, which has a relatively large value of the wheat price elasticity. The large value of the USSR's elasticity may depend on the time lag of price changes to the USSR's volatile purchasing behavior as previously discussed. The income elasticities are negative for the developed countries other than Japan. This means that wheat is an inferior good for these countries. The income elasticities in the LDCs are large; especially the elasticity for the rest of the LDCs is very large. These income elasticities correspond to the fact that wheat imports on the commercial basis have very rapidly increased in the LDCs during the last two decades. However, it is noted that the magnitude
Table 5.2. Price and income elasticities of total import demand for wheat by importing region\(^a\)

<table>
<thead>
<tr>
<th>Importing region</th>
<th>Price of wheat</th>
<th>Price of substitutes(^b)</th>
<th>Real income</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC-6</td>
<td>-0.4748</td>
<td>0.6668</td>
<td>-0.4098</td>
</tr>
<tr>
<td>EC-3</td>
<td>-1.1410</td>
<td>1.2368</td>
<td>-0.5197</td>
</tr>
<tr>
<td>Japan</td>
<td>-0.0483</td>
<td>--</td>
<td>0.3512</td>
</tr>
<tr>
<td>Rest of DCs</td>
<td>-1.0303</td>
<td>1.5246</td>
<td>-1.2144</td>
</tr>
<tr>
<td>NICs</td>
<td>-0.7917</td>
<td>0.3903</td>
<td>0.8909</td>
</tr>
<tr>
<td>OPEC</td>
<td>-0.4658</td>
<td>--</td>
<td>1.9116</td>
</tr>
<tr>
<td>Rest of LDCs</td>
<td>--</td>
<td>--</td>
<td>5.1460</td>
</tr>
<tr>
<td>China</td>
<td>-0.7673</td>
<td>0.7799</td>
<td>--</td>
</tr>
<tr>
<td>Eastern Europe</td>
<td>-0.4986</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>USSR</td>
<td>-2.0847</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

\(^a\)This table is based on the estimated coefficients and mean values of the variables.

\(^b\)Corn for the DCs or rice for the LDCs and China.
of the income elasticity is clearly different by group of countries. The income elasticities in the LDCs seem to be related to the stage of economic development; the NICs may change the diet pattern to the similar one of the developed countries, and it may be followed by OPEC.

The supply side equations were estimated to analyze the domestic factors of wheat-exporting countries. The estimated production equations showed that producers responded to the wheat export price, except Australia in which producers are highly insulated from the world market. In the original production model, the variable of the alternative crop price was also included. However, the relative price of wheat to the alternative crop price did not show significant effect on production in most countries, except France. Consumption was related to wheat export price in some degree only in Canada and the U.S. Argentina and France did not show any significant coefficient of the wheat price variable in the consumption equation. For Australia, the government-determined domestic consumption price was introduced to obtain the price effect on wheat consumption. The inventory equations indicated that only Australia and the U.S. had price effects on the inventory level. Otherwise, inventories were explained by production and lagged inventories.

The calculated price and income elasticities for each supply side equation are summarized in Table 5.3. The price elasticities of production are 0.3812 for Argentina, 0.1000 for France, 0.2270 for Canada, and 0.3501 for the U.S.; all of them are much less than unity. The own-price elasticities of domestic consumption are -0.0734 for
Table 5.3. Price and income elasticities of supply side equations by exporting country^a

<table>
<thead>
<tr>
<th>Variable</th>
<th>Argentina</th>
<th>Australia</th>
<th>Canada</th>
<th>France</th>
<th>U.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat price</td>
<td>0.3812</td>
<td>--</td>
<td>0.2270</td>
<td>0.1000</td>
<td>0.3501</td>
</tr>
<tr>
<td>Consumption:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat price</td>
<td>--</td>
<td>-1.3281(^b)</td>
<td>-0.0734</td>
<td>--</td>
<td>-0.2033</td>
</tr>
<tr>
<td>Livestock price</td>
<td>--</td>
<td>0.2274</td>
<td>--</td>
<td>0.5937</td>
<td>0.1376</td>
</tr>
<tr>
<td>Real income</td>
<td>--</td>
<td>-0.5663</td>
<td>0.0326</td>
<td>-0.1719</td>
<td>0.4005</td>
</tr>
<tr>
<td>Inventories:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat price</td>
<td>--</td>
<td>-0.1632</td>
<td>--</td>
<td>--</td>
<td>-0.1271</td>
</tr>
</tbody>
</table>

^a This table is based on the estimated coefficients and mean values of the variables.

^b Wheat price for consumption in Australia is the home consumption price.
Canada, -0.2033 for the U.S., and -1.3281 for Australia, whose own-price is the home consumption price determined by the government. The livestock price elasticities of wheat demand showed up only for Australia, France, and the U.S.; these are 0.2274, 0.5937, and 0.1376, respectively. The income elasticities of demand are -0.5663 for Australia, -0.1719 for France, 0.0326 for Canada and 0.4005 for the U.S.; Australia and France show the inferior good results. It is again noted that the income effect on wheat consumption in this study includes some effect of income on consumption of meat and dairy products through wheat demand for feed use. The price elasticity of inventories showed up only for Australia and the U.S.; these are -0.1632 and -0.1271, respectively.

Finally, combining the import demand and trade flow equations with the price linkage equations leads to derivation of the export price elasticities of the aggregated total export demand. The derivative of the total export demand with respect to the export price for country i can be written as follows:

$$\frac{\partial X_i}{\partial P_{W,1}} = \sum_{j=1}^{10} \frac{\partial X_{ij}}{\partial P_{ij}} \cdot \frac{\partial P_{ij}}{\partial P_{W,1}} \cdot \frac{\partial P^X_{ij}}{\partial P_{W,1}}$$

$$= \sum_{j=1}^{10} \frac{1}{P_{ij}} \left[ (S_{ij})^2 \cdot N_j \right] \cdot \frac{\partial M_{ij}}{\partial P_j} - \sigma_j \cdot B_{ij} \cdot (1 - S_{ij}) \cdot \frac{\partial P^X_{ij}}{\partial P_{W,1}}$$

where definitions of the variables are the same as used in the last section of Chapter III. If all the export prices are expressed in U.S. dollar and population is evaluated at mean value, then this derivative can be
calculated for each exporting country by using the estimated coefficients of the import demand, trade flow, and price linkage equations. Then, the export price elasticities of the total export demand can be derived and they are summarized in Table 5.4. The elasticities are -1.1791 for Argentina, -0.3692 for Australia, -0.8455 for Canada, -0.8915 for France, and -0.4363 for the U.S. It is noted that the elasticities of Argentina, Canada, and France are greater than those of Australia and the U.S. Although there is no general consensus reached on the magnitude of the elasticities, these figures obtained in this study do not conflict with past studies on export demands for wheat. For example, the value of the elasticity for the U.S. is very similar to the value estimated by Gallagher et al. [27]; their value of the elasticity for the U.S. is -0.413.
Table 5.4. Export price elasticities of total demand by exporting country

<table>
<thead>
<tr>
<th>Exporting Country</th>
<th>Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>-1.1791</td>
</tr>
<tr>
<td>Australia</td>
<td>-0.3692</td>
</tr>
<tr>
<td>Canada</td>
<td>-0.8455</td>
</tr>
<tr>
<td>France</td>
<td>-0.8915</td>
</tr>
<tr>
<td>United States</td>
<td>-0.4363</td>
</tr>
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</table>

*Elasticities are calculated from the derivatives based on Equation (5.1) and mean values of the variables.*
CHAPTER VI. EVALUATION OF THE ECONOMETRIC MODEL

This chapter presents an examination of the econometric model estimated in the previous chapter with regard to the ability to predict past events. The model is evaluated by simulating the past performance of the world wheat trade. Furthermore, the model is used to analyze some impacts of autonomous changes in exogenous variables on the world wheat trade.

Validation of the Model

In order to complete the system of the world wheat trade model, the following definitions and identities are introduced in addition to the estimated behavioral equations in the previous chapter; the total import demand defined as per capita import demand multiplied by population, the normalized import price defined as the import price divided by the base-year import price, the import price index defined as the fixed-weighted average of the normalized import prices, the total domestic demand in an exporting country defined as the per capita domestic demand multiplied by population, the total export demand defined as the aggregated individual import demand over region, and the identities to represent the market clear conditions. Additionally, it is assumed that the allocation of the imports aggregated for Argentina, France, and the U.S. in China, and for Argentina, Australia, and France in Eastern Europe and the USSR is determined exogenously. Thus, the complete system of the world wheat trade model consists of 116 behavioral equations, 76 definitions, and 5 identities; totally, 197 equations and the same number of endogenous
variables. The number of exogenous variables is 155.

The system of equations of the model is dynamically simulated over the 1967-78 period. In the estimation of the trade flow equations, the years of 1964 to 1966 are used as the base period. Therefore, the 1967-78 period represents the longest period over which the simulation can be performed. The simulation procedure is dynamic because the solved values are used for lagged values of endogenous variables rather than the actual values for the lagged endogenous variables. Most of the behavioral equations are not linear with respect to the endogenous variables since the price and income variables are expressed in real terms or in relative price terms, except the inventory equations which call for the price variables in nominal terms. Therefore, a nonlinear simulation procedure, SIMNLIN in SAS/ETS [79], is used to solve the model. Among the solution methods available, Newton's method is applied because it allows implicit equations in the system to be solved.

The criterion used to evaluate the simulation model in this study is the fit of the individual variables. The model is simulated over the past period and it is examined how closely each endogenous variable tracks its corresponding historical data series. The most commonly used quantitative measure to evaluate how closely individual variables track their corresponding data series is called the RMS (root-mean-square) simulation error. The RMS error is defined as

$$\text{RMS error} = \sqrt{\frac{1}{T} \sum_{t=1}^{T} (Y_t^* - Y_t)^2}$$

where $Y_t^*$ = simulated value of the endogenous variable,
\[ Y_t = \text{actual value of the endogenous variable,} \]
\[ T = \text{number of periods in the simulation.} \]

Therefore, the RMS error is a measure of the deviation of the simulated variable from its actual time path. The magnitude of this error must be compared with the average size of the variable in equation for the evaluation. Another measure commonly used is the RMS percent error, which evaluates the individual deviation in percentage terms; therefore, it is required to divide the deviation by the actual value. However, several variables in the wheat trade model take zero value in the data set. For this reason, the RMS percent error is not used in this study. (For further discussions on evaluating simulation models, see Pindyck and Rubinfeld [67].)

The RMS errors and the ratios of the RMS error to mean value for the major variables, as well as the mean values of the variables for the simulation period, are presented in Table 6.1. For comparison of the prices internationally, all the export prices are expressed in U.S. dollar terms rather than domestic currency terms. The RMS errors of the export prices in the ratio to mean value show that the U.S. export price is well simulated with the smallest value of the ratio among the export prices. Other export prices also have reasonably small RMS errors. The total export variables show similar results to the export prices. The U.S. and Australia are especially well-simulated for the exports with small RMS errors compared with the mean values. The RMS errors of production in the ratio to mean value are smaller than those of exports; the simulation of production is better than that of exports for every
Table 6.1. RMS errors and ratios to mean value for selected endogenous variables based on 1967-78 dynamic simulation

<table>
<thead>
<tr>
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<th>RMS error</th>
<th>RMS error/mean (percent)</th>
</tr>
</thead>
<tbody>
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<td>35,46</td>
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<td>28,56</td>
<td>30,47</td>
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<td>106,46</td>
<td>23,22</td>
<td>21,81</td>
</tr>
<tr>
<td>PW4</td>
<td>101,63</td>
<td>23,22</td>
<td>21,81</td>
</tr>
<tr>
<td>PW5</td>
<td>100,89</td>
<td>13,39</td>
<td>13,27</td>
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<tr>
<td>Total exports:</td>
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<td>773</td>
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<td>7287</td>
<td>950</td>
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<tr>
<td>X3</td>
<td>11302</td>
<td>2113</td>
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<tr>
<td>X4</td>
<td>2849</td>
<td>963</td>
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<tr>
<td>X5^a</td>
<td>22389</td>
<td>2444</td>
<td>10,92</td>
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<td>Production:</td>
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<td>PD2</td>
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<td>28,48</td>
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<td>IN4</td>
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<td>IN5</td>
<td>35,61</td>
<td>3,27</td>
<td>9,18</td>
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</table>

^aIncluding PL 480 exports.
Table 6.1. (Continued)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>RMS error</th>
<th>RMS error (percent)</th>
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<td>RMS error</td>
<td>RMS error/mean (percent)</td>
</tr>
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<td>------</td>
<td>-----------</td>
<td>-------------------------</td>
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<td>Trade flows (continued):</td>
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</tr>
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<td>43.05</td>
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<td>1035</td>
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<tr>
<td>X510</td>
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<td>1609</td>
<td>80.33</td>
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</table>
exporting country. All the consumption variables show very small RMS errors; in fact, consumption does not vary so much over time. Additionally, French exports to other EC-5 countries are also well-behaved in the simulation. Inventories, as well, show fairly good results; among others, the RMS error for the U.S. is very small.

Turning to the importing regions, the total import demands are generally well-simulated, except the USSR whose RMS error is more than half of the mean value. Japan has a very small RMS error, which is less than 4 percent of the mean value. The EC-6, the NICs, OPEC, and the rest of the LDCs also have small RMS errors; each RMS error is about 10 percent of the mean value. The import price indices show that all the RMS errors are less than 20 percent of the mean value, except the USSR whose error is about a quarter of the mean value.

The trade flows show a variety of the RMS errors. Generally, the trade flows from Canada and the U.S. are well-simulated, but some of the trade flows from Argentina, Australia, and France show large RMS errors; the quantities of the latter trade flows are generally small. Most of the trade flows to the centrally planned economies show the RMS errors which are more than a half of the mean value, except China's imports from Australia and Canada. This means that it is difficult to explain the trade flows to these regions by the model developed in this study.

Finally, the fitness of the model can be more visible if the simulated values are plotted against the actual values on a same graph. To help the evaluation of the model, the export prices of the five
exporting countries, which may be considered as the most important variables in the model, are graphed for the simulated and actual values in Figures 6.1 through 6.5. The figure for the U.S. shows the visibly good fitness of the export price. Other figures also show the good performance of the simulation.

Impact Multiplier Analysis

The econometric model developed in this study can be used to predict how a change in one variable is likely to affect other variables. If the model's parameters are such that the simulation solution is stable, the initial increase in a given exogenous variable would be expected to result in ever-diminishing changes in each endogenous variable. These changes in each endogenous variable are called "dynamic multipliers". The initial (first-period) change in each endogenous variable is called the "impact multiplier". The "total long-run multiplier" is just the sum of all the dynamic multipliers over time. (See Pindyck and Rubinfeld, p. 392 [67].)

Using the estimated model, the impacts of changes in several exogenous variables on world wheat trade are examined. The scenarios and corresponding exogenous variables for the impact multiplier analysis are as follows:

Scenario 1: What would have happened, if the world per capita income had increased by 10 U.S. dollars? Set YE1-YE7, and Y2-Y5 at 10 U.S. dollars more than the actual level.
Figure 6.1. Predicted and observed values for wheat export price of Argentina, 1967-78 dynamic simulation.
Figure 6.2. Predicted and observed values for wheat export price of Australia, 1967-78 dynamic simulation.
Figure 6.3. Predicted and observed values for wheat export price of Canada, 1967-78 dynamic simulation
Figure 6.4. Predicted and observed values for wheat export price of France, 1967-78 dynamic simulation
Figure 6.5. Predicted and observed values for wheat export price of the U.S., 1967-78 dynamic simulation
Scenario 2: What would have happened, if the population in the less developed countries had been 1 percent more than the actual population? Set N5, N6, and N7 at 1 percent more than the actual level.

Scenario 3: What would have happened, if the PL 480 shipments had been ended? Set A5, A7, and all ADs at zero.

Scenario 4: What would have happened, if only the changes in importers' preference in the determination of suppliers had occurred? Set T and TD at one more than the actual level.

The results of the analysis are summarized in Table 6.2 for the selected endogenous variables. The impact multipliers, which show the immediate effects of such changes as in the scenarios on the world wheat economies, are computed from the results of the simulations for 1978. Therefore, the multipliers may not be valid for variable values significantly different from their 1978 values.

The results of Scenario 1, income effect, are in the first column in Table 6.2. Increases in per capita income by 10 U.S. dollars in the world, except in the centrally planned economies, would have resulted in increases in the export prices by $10.76 for Argentina, $10.77 for Australia, $6.43 for Canada, $19.65 for France, and $8.50 for the U.S.; all the export prices are expressed in U.S. dollars per metric ton. This variation of the export price increases would have caused demand shifts at the same time because the relative prices would have changed. Exports of wheat would have increased in Australia, Canada, and the
Table 6.2. Immediate impacts of changes in some exogenous variables on world wheat trade

<table>
<thead>
<tr>
<th>Variable</th>
<th>Scenario 1 (Income change)</th>
<th>Scenario 2 (Population change)</th>
<th>Scenario 3 (PL 480 change)</th>
<th>Scenario 4 (Preference change)</th>
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</thead>
<tbody>
<tr>
<td>Export price:</td>
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<tr>
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<td>1.83</td>
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<tr>
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<tr>
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</tr>
<tr>
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<td>3.10</td>
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<tr>
<td>PW5</td>
<td>8.50</td>
<td>0.84</td>
<td>-18.37</td>
<td>-6.75</td>
</tr>
<tr>
<td>Total exports:</td>
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<td></td>
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<td>X1</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>X2</td>
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<td>19.0</td>
<td>71.1</td>
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</tr>
<tr>
<td>X3</td>
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<td>1.3</td>
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</tr>
<tr>
<td>X4</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>X5</td>
<td>616.6</td>
<td>63.6</td>
<td>1615.8^a</td>
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</tr>
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<tr>
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<td>-9.1</td>
<td>28.1</td>
<td>45.1</td>
</tr>
<tr>
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<td>-18.2</td>
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<td>2.2</td>
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<td>M7</td>
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<td>-3.6</td>
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<td>-369.8</td>
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<td>0.016</td>
<td>-0.051</td>
<td>-0.081</td>
</tr>
<tr>
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<td>0.013</td>
<td>-0.008</td>
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<tr>
<td>P3</td>
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<td>0.013</td>
<td>-0.149</td>
<td>-0.038</td>
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<tr>
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<td>0.016</td>
<td>-0.135</td>
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<td>-0.017</td>
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<td>0.016</td>
<td>-0.107</td>
<td>-0.017</td>
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<td>P7</td>
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<td>0.015</td>
<td>-0.049</td>
<td>-0.014</td>
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<tr>
<td>P8</td>
<td>0.123</td>
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<td>-0.041</td>
<td>0.038</td>
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<tr>
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<td>0.123</td>
<td>0.010</td>
<td>0.023</td>
<td>0.055</td>
</tr>
</tbody>
</table>

^aChanges in commercial exports.
the largest increase would have been U.S. exports. However, French exports would have declined a little; French price increases would have been the largest. Argentina has domestically no response to income and current price; therefore, the export level would not have immediately changed. For importing regions, the income effect is different by region. The greatest increase in wheat imports would have taken place in the rest of the LDCs. Japan and OPEC would have increased their imports by a small amount. However, the NICs would have reduced their imports because the price increases would have had larger effects than the income increase. All other regions also would have suffered from the price increases and reduced their imports.

The effects of Scenario 2, caused by the population increases in the LDCs by one percent of the actual population, are shown in the second column. The impact on export prices would have been larger for Argentina and France than others; these two countries would have experienced the price increase by $1.83 and $1.61 in U.S. dollars per metric ton, respectively, whereas other price increases would have been less than $1.00 in U.S. dollars per metric ton. Argentina and France have domestically no response to current price, although they have production response to lagged price. Therefore, the current price change is not linked to the current export level of these two countries. The export increases would have occurred by 19,0 tmt (thousand metric tons) in Australia, by 1.3 tmt in Canada, and by 63.6 tmt in the U.S. The increases in imports in the LDCs would have been 36.0 tmt in the NICs, 52.5 tmt in OPEC, and 145.4 tmt in the rest of the LDCs. All other
regions would have reduced imports because of the higher prices.

Scenario 3 studies the effects of a sudden decrease in PL 480 shipments to zero. The simulation is based on the 1978 data, so the effects are computed for assumed ending PL 480 exports in 1978. The results are in the third column. Ending PL 480 exports would have resulted in a sharp decrease in the U.S. export price by $18.37 in U.S. dollars per metric ton, although the U.S. commercial exports would have increased by 1.6 million metric tons. The sharp price decline would have occurred because the role of PL 480 exports was an important demand shifter for the U.S. market. On the other hand, the significant part of the PL 480 shipments would have been replaced with the commercial exports. Additionally, the sharp decline of the U.S. price would have caused an increased export demand for U.S. wheat. Ending PL 480 exports would have caused some changes in other exporting countries as well; increases in the export prices of all other exporters and increases in exports of Australia and Canada. For importing regions, a notable increase in imports would have been observed in the rest of the LDCs. The price decline of U.S. exports would have led most regions to increase imports, except Eastern Europe and the USSR, who would have decreased their total imports of wheat, depending on the price increases in other exporting countries.

The final examination, Scenario 4, tries to find the pure effect of preference changes in importing regions in the determination of import suppliers. The results are presented in the fourth column. The figures indicate that yearly changes in importers' preference favor Australia's
price and suppress Argentina's and U.S. prices; the price of Australia's exports would have increased by $11.6 in U.S. dollars per metric ton, whereas the prices of Argentina's and U.S. exports would have declined by $10.9 and $6.7 in U.S. dollars per metric ton, respectively if only the preference changes had occurred. The effects on Canada and France are small. The export level also would have been changed in Australia and the U.S., which would have had an increase by 234 tmt, and a decrease by 509 tmt, respectively. The effects on the total imports are mixed. The EC-3, China, and the USSR would have decreased their imports and other regions would have increased imports, except the rest of the LDCs, which has no response to price in the determination of total imports. In the rest of the LDCs, only the market shares would have shifted within the given total imports.
CHAPTER VII. SUMMARY AND CONCLUSIONS

The central purpose of this study has been to analyze the structure and mechanism of commercial world wheat trade with a primary emphasis on the networks of international trade flows of wheat. This has been accomplished by first dividing the world into the five exporting countries and the ten importing regions. The five exporting countries are Argentina, Australia, Canada, France, and the United States. The breakdown for importing regions was based on the degree of similarity in response to price changes; the ten importing regions are the six original EEC countries (EC-6), the three new EEC countries (EC-3), Japan, the rest of the DCs (developed countries), the newly industrializing less developed countries (NICs), the members of OPEC, the rest of the LDCs (less developed countries), Eastern Europe, China, and the USSR. All the trade flows between the exporting countries and the importing regions have been examined in this study.

To investigate the interrelated world wheat economies and the trade linkages, an econometric model of world wheat trade was developed. The starting point of developing a wheat trade model was to recognize the fact that wheat is differentiated by place of production; suppliers of wheat are not perfectly substitutable for one another from the importers' viewpoint. The theoretical framework of the demand structure of product differentiation was developed by Armington [7]. His model assumes a two-stage budgeting procedure and the constant-elasticity-of-substitution (CES) function as a sub-utility function or a quantity index for commodity whose products are differentiated. Armington's model
was modified to make it possible to estimate the elasticity of substitution by Hickman and Lau [32]. The submodel of trade flows in this study is based on the model of Hickman and Lau. All the trade flows were specified in the trade flow equations assuming the constant elasticity of substitution in each market region. In the estimation of the equations, time and dummy variables were introduced to explain changes in importers' preference.

Total import demand for all wheat was assumed to be determined in the framework of the traditional excess import demand theory. Consumption, production, and inventories were incorporated in deriving the total import demand equation. In estimating the total wheat import demand, special attention was paid to price and income variables because they must be specified in a common unit when considering different countries.

The analysis of the exporting countries was conducted in the estimation of supply side equations, which consist of a production equation, a domestic demand equation, and an inventory equation for each exporting country. Each equation was specified and estimated separately to identify the role of each domestic factor in export supply.

All these equations were incorporated into a system of the world wheat trade model. The system was completed by introducing the price linkage equations connecting export prices with import prices, and the quantity balanced equations.

The results of the econometric estimations were fairly good and helpful to understand the real world of wheat trade. The estimation of
the elasticities of substitution in trade flow equations indicated that most of the regions had limited response to relative price in the determination of import suppliers, except the rest of the LDCs, which had a relatively large estimate. The estimated elasticities of substitution were as follows: 0.7538 for the EC-3, 0.4768 for the rest of the DCs, 0.6075 for OPEC, 2.1214 for the rest of the LDCs, and 0.3163 for Eastern Europe. The estimated coefficients for the elasticity of substitution in all other importing regions were not significantly different from zero; therefore, they were set at zero in the model. It was noted that only the rest of the LDCs had the elasticity of substitution which was more than unity. This importing group, now the dominant importer of wheat, is characterized by poverty and extreme limitations on foreign exchange, which lead to the elastic substitutability among import suppliers.

In contrast to the elasticities of substitution, the total import demand equations showed significant demand response to import price in most of the regions except Japan and the rest of the LDCs. The calculated own-price elasticities were about unity for the EC-3 and the rest of the DCs, and less than unity for all other regions except the USSR, which had a relatively large elasticity. This large elasticity of the USSR might depend on the time lag of the export price changes behind the USSR's volatile purchasing behavior. Income elasticities were also derived; they were negative for the developed regions except Japan, and positively large for the less developed regions, especially for the rest of the LDCs. Combining the results of the total import demand
equations with the trade flow equations made clear the structure of import demands. For example, the rest of the LDCs could be considered as determining the total level of imports by domestic production, inventory level, income, and the concessional imports regardless of import price, but seeking to buy the determined quantity at lower prices.

The estimation of the supply side equations also resulted in better understanding of the supply side structure of wheat exports. The export price of wheat influenced Argentina's production, Australia's inventories, Canada's production and consumption, France's production, and U.S. production, consumption, and inventories. To explain the changes in production, a yield variation index indicating weather conditions was introduced. It influenced production in the four exporting countries except the U.S., whose coefficient was not significantly different from zero. The livestock sector was linked to domestic wheat consumption by introducing the price of livestock, which affected wheat consumption in Australia, France, and the U.S. Income coefficients in the consumption equation were negative for Australia and France, and positive for Canada and the U.S. In all the exporting countries the inventory level was strongly related to the level of production and the lagged inventories.

The price linkage equations were also estimated and the results provided some findings on the structure of price linkages between exporting countries and importing regions. The estimation of the price linkage equations made it possible to calculate the export price elasticities of the total export demand for each exporting country. The calculated elasticities were -1.1791 for Argentina, -0.3692 for Australia,
-0.8455 for Canada, -0.8915 for France, and -0.4363 for the U.S.

The complete system of the world wheat trade model was evaluated by simulating the past performance of world wheat trade. The model could simulate most of the variables with small RMS (root-mean-square) errors compared with mean value. Especially, the U.S. export price and the level of U.S. exports were well simulated with the smallest RMS error in the ratio to the mean value among the exporting countries. The simulation results showed a good ability of the model to simulate the total exports and imports, but they showed relatively large RMS errors for some trade flows, especially, for those to the centrally planned economies.

The simulation model was also used to analyze the impacts of changes in several exogenous variables on the world wheat trade. The following effects were examined: the effect of increases in world per capita income, the effect of population increases in the LDCs, the effect of ending the PL 480 exports, and the effect of preference changes in importing regions in the choice of suppliers.

One of the limitations of the model developed in this study is taking a free trade view of the world wheat market. In reality, most countries have the internal market prices which are insulated from the world market by a variety of government interventions. However, it is extremely difficult to collect data of internal prices internationally which are consistent and usable for the time series analysis. Instead, some policy variables may be introduced into the model. This case may cause problems of the selection of the appropriate policy variables and
their measurements. In this study, only dummy variables were introduced to show supply control programs in exporting countries. Some policy variables such as the threshold price in the EC countries were attempted to be introduced. However, the results failed to be significant. The most important policy variable in this study was the PL 480 shipments, which have largely influenced the commercial imports in the LDCs. The PL 480 shipments were treated as exogenous in this study, but they could have been endogenized because the PL 480 shipments have not been completely independent of the world wheat markets.

The model in this study was developed with a theoretically sound background. Testing theory is one of the general objectives of agricultural trade modeling. In this study, much attention was paid to Armington's theory of demand for products differentiated by place of production. In addition to the failure of finding significant response to price in the choice of suppliers for half of the importing regions, the equality of the elasticity of substitution between all pairs of exporters was rejected in some regions in testing the hypothesis. These problems resulted in the poor predictability of the trade flows in some cases, especially, in the cases of the centrally planned economies. This means that a uniform application of Armington's approach to all importing regions is not appropriate. The choice of import suppliers and the share determination process might be different from country to country.

Although it has not been an easy task to challenge the world wheat markets, much has been learned about the world of wheat trade during the
process of this study. It is hoped that the analysis conducted in this study will make some contribution to knowledge of the interrelationships among trading countries for further study on the world's wheat economies.
REFERENCES


First and foremost, I would like to express my deep appreciation to Dr. Earl O. Heady, who has served as my major professor. His support, guidance, and encouragement greatly contributed to the completion of my dissertation.

Appreciation is extended to Dr. Young W. Kihl, Dr. William H. Meyers, Dr. Vincent A. Sposito, and Dr. Dennis R. Starleaf for serving on my graduate committee.

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I owe thanks to Mr. Brian Holding, who read the draft of my dissertation and made necessary corrections. Dr. Anthony Turhollow, my former office mate, also helped me with reading a part of my dissertation at the earlier stage. Mrs. Barbara Dubberke did an excellent job of the final typing. I would like to thank all of them.

Very special appreciation is reserved for my wife, Yayoi, who constantly provided affection, support, and encouragement. She also did a number of miscellaneous jobs for me including the preliminary typing and constructing the tables. Without her help, this study could never have been completed. Our daughter, Shinobu, also deserves to be appreciated for her patience. For all of this, I consider myself profoundly fortunate.
APPENDIX A: VARIABLES USED IN THE WORLD WHEAT TRADE MODEL
Table A.1. Definitions and data sources of the variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Endogenous variables</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PDI&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Wheat production in country I, million metric tons; I=1,2,\ldots,5.</td>
<td>FAO [24]</td>
</tr>
<tr>
<td>DCI</td>
<td>Total consumption of wheat in country I, 1000 metric tons; I=1,2,\ldots,5.</td>
<td>USDA [109]</td>
</tr>
<tr>
<td>DCE</td>
<td>Total imports of French wheat in EC-5 countries, 1000 metric tons.</td>
<td>UN [103]</td>
</tr>
<tr>
<td>CSI</td>
<td>Per capita consumption of wheat in country I, kilograms; I=1,2,\ldots,5.</td>
<td>calculated</td>
</tr>
<tr>
<td>CSE</td>
<td>Per capita imports of French wheat in EC-5 countries, kilograms.</td>
<td>calculated</td>
</tr>
<tr>
<td>XI</td>
<td>Total exports of wheat in country I, 1000 metric tons; I=1,2,\ldots,5.</td>
<td>UN [103]</td>
</tr>
<tr>
<td>INI</td>
<td>Ending inventories of wheat in country I derived from production and beginning inventories less consumption and exports, million metric tons; I=1,2,\ldots,5.</td>
<td>calculated</td>
</tr>
<tr>
<td>MJ&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Total commercial imports of wheat in region J from five major exporting countries, 1000 metric tons; J=1,2,\ldots,10.</td>
<td>UN [103]</td>
</tr>
<tr>
<td>MQJ</td>
<td>Per capita commercial imports of wheat in region J from five major exporting countries, 1000 metric tons; J=1,2,\ldots,10.</td>
<td>calculated</td>
</tr>
</tbody>
</table>

<sup>a</sup>Suffix I represents exporting countries (1 = Argentina, 2 = Australia, 3 = Canada, 4 = France, and 5 = U.S.) and suffix J represents importing regions (1 = EC-6, 2 = EC-3, 3 = Japan, 4 = rest of DCs, 5 = NICs, 6 = OPEC, 7 = rest of LDCs, 8 = China, 9 = Eastern Europe, and 10 = USSR).
Table A.1. (Continued)

<table>
<thead>
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<th>Variable</th>
<th>Definition</th>
<th>Data source</th>
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<tr>
<td>XIJ$^a$</td>
<td>Commercial imports of wheat in region J from country I, 1000 metric tons; I=1,2,...,5; J=1,2,...,10.</td>
<td>UN [103], USDA [107, 110, 111]</td>
</tr>
<tr>
<td>PWI</td>
<td>Export price of wheat in country I, defined as unit value of total exports of wheat per metric ton in country I; pesos for I=1, Australian $ for I=2, Canadian $ for I=3, francs for I=4, U.S. $ for I=5.</td>
<td>UN [103], IMF [36]</td>
</tr>
<tr>
<td>PXIJ</td>
<td>Import price in region J of wheat from country I, defined as unit value of wheat imports in region J from country I, U.S. $ per metric ton; I=1,2,...,5; J=1,2,...,10.</td>
<td>UN [103]</td>
</tr>
<tr>
<td>PIJ</td>
<td>Normalized import price in region J of wheat from country I, 1964-1966 Average = 1; I=1,2,...,5; J=1,2,...,10.</td>
<td>calculated</td>
</tr>
<tr>
<td>PJ</td>
<td>Import price index of wheat in region J, defined as a fixed-weighted average of normalized import prices; J=1,2,...,10.</td>
<td>calculated</td>
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</table>

**Exogenous variables**

<table>
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<th>Definition</th>
<th>Data source</th>
</tr>
</thead>
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<tr>
<td>NI</td>
<td>Population in country I, millions; I=1,2,...,5.</td>
<td>UN [104]</td>
</tr>
<tr>
<td>NE</td>
<td>Population in EC-5 countries, millions.</td>
<td>UN [104]</td>
</tr>
<tr>
<td>ERI</td>
<td>Exchange rate of country I, expressed in the currency of country I per U.S. dollar; I=1,2,...,5.</td>
<td>IMF [36]</td>
</tr>
<tr>
<td>CPII</td>
<td>Consumer price index in country I, 1965 = 1.00; I=1,2,...,5.</td>
<td>IMF [36], UN [105]</td>
</tr>
<tr>
<td>Variable</td>
<td>Definition</td>
<td>Data source</td>
</tr>
<tr>
<td>----------</td>
<td>------------</td>
<td>-------------</td>
</tr>
<tr>
<td>YI</td>
<td>Per capita real disposable income in country I at constant 1965 prices; 1000 Australian $ for I=2, Canadian $ for I=3, 1000 francs for I=4, U.S. $ for I=5.</td>
<td>UN [106], IMF [36]</td>
</tr>
<tr>
<td>PFI</td>
<td>Price index of variable agricultural inputs in country I, defined as price index of production requisites in country I, 1965 = 1.00; I=3,4,5.</td>
<td>FAO [24]</td>
</tr>
<tr>
<td>PLI</td>
<td>Price index of livestock in country I, 1965 = 1.00; cattle and sheep for I=2, livestock and products for I=4 and I=5.</td>
<td>FAO [24]</td>
</tr>
<tr>
<td>WI</td>
<td>Yield variation index in country I, defined as percent deviation of actual yield from expected level of the yield; I=2,3,4,5.</td>
<td>calculated</td>
</tr>
<tr>
<td>PC4</td>
<td>Export price of barley in France, defined as unit value of barley exports by France, francs per metric ton.</td>
<td>FAO [25]</td>
</tr>
<tr>
<td>G2</td>
<td>Policy dummy variable for Australian wheat delivery quotas; set at 1 for 1970-72, 0 otherwise.</td>
<td>------</td>
</tr>
<tr>
<td>G3</td>
<td>Policy dummy variable for Canadian LIFT program; set at 1 for 1970, 0 otherwise.</td>
<td>------</td>
</tr>
<tr>
<td>HCP</td>
<td>Home consumption price of wheat in Australia, Australian $ per metric ton.</td>
<td>Richards [70]</td>
</tr>
<tr>
<td>PWF</td>
<td>Export price of French wheat to EC-5 countries, defined as unit value of exports of French wheat to EC-5 countries, U.S. $ per metric ton.</td>
<td>UN [103]</td>
</tr>
<tr>
<td>NJ</td>
<td>Population in region J, millions; J=1,2,...,10.</td>
<td>UN [104]</td>
</tr>
<tr>
<td>Variable</td>
<td>Definition</td>
<td>Data source</td>
</tr>
<tr>
<td>----------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>YEJ</td>
<td>Effective per capita real disposable income in region J at constant 1965 prices, adjusted for exchange rate changes, 1000 U.S. $; J=1,2,...,7.</td>
<td>UN [106],</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IMF [36]</td>
</tr>
<tr>
<td>CPEJ</td>
<td>Effective consumer price index in region J, adjusted for exchange rate changes, 1965 = 1.00; j=1, 2,...,6.</td>
<td>UN [105],</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IMF [36]</td>
</tr>
<tr>
<td>QJ</td>
<td>Per capita domestic production of wheat in region J, kilograms; J=3,6,7,8.</td>
<td>FAO [24]</td>
</tr>
<tr>
<td>STJ-1</td>
<td>Lagged ending inventories of wheat in region J, divided by population, kilograms; J=2,5,6,7,10.</td>
<td>USDA [109]</td>
</tr>
<tr>
<td>PAJ</td>
<td>Price of substitutes for wheat in region J, defined as unit value of U.S. corn exports for J=1,2,4 and unit value of U.S. and Thailand's rice exports for J=5,8; U.S. $ per metric ton.</td>
<td>FAO [25]</td>
</tr>
<tr>
<td>ADJ</td>
<td>Total noncommercial imports of wheat in region J, defined as PL 480 imports for J=4,5,6,7, and imports from USSR for J=9; 1000 metric tons.</td>
<td>USDA [107,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>110, 111]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IWC [38]</td>
</tr>
<tr>
<td>AJ</td>
<td>Per capita noncommercial imports of wheat in region J, kilograms; J=4,5,6,7,9.</td>
<td>calculated</td>
</tr>
<tr>
<td>T</td>
<td>Time trend variable for preference changes; set at zero in the base period of 1964-1966.</td>
<td>-----</td>
</tr>
<tr>
<td>TD</td>
<td>Time dummy variable, equated to T if year ( \geq 1973 ), 0 otherwise.</td>
<td>-----</td>
</tr>
<tr>
<td>D</td>
<td>Dummy variable, equated to 1 if year ( \geq 1973 ), 0 otherwise.</td>
<td>-----</td>
</tr>
<tr>
<td>Variable</td>
<td>Definition</td>
<td>Data source</td>
</tr>
<tr>
<td>----------</td>
<td>------------</td>
<td>-------------</td>
</tr>
<tr>
<td>YR</td>
<td>Time trend for technological changes; last two digits of the year.</td>
<td>-----</td>
</tr>
<tr>
<td>D8</td>
<td>Dummy variable for China's increases in wheat imports in 1977 and 1978; set at 1 for 1977 and 1978, 0 otherwise.</td>
<td>-----</td>
</tr>
<tr>
<td>DYR</td>
<td>Dummy variable for an extraordinary disturbance term; set at 1 if year = YR, 0 otherwise; YR = 69,70,71,73, 74,76,78.</td>
<td>-----</td>
</tr>
<tr>
<td>SHIJ</td>
<td>Share of country I in aggregated trade flows in CPs; I=1,4,5 for J=8; I=1,2,4, for J=9 and 10.</td>
<td>UN [103]</td>
</tr>
<tr>
<td>SIJ</td>
<td>Average market share of country I in region J in the base period of 1964-1966; I=1,2,...,5; J=1, 2,...,10.</td>
<td>UN [103]</td>
</tr>
<tr>
<td>BIJ</td>
<td>Average wheat exports of country I to region J in the base period 1964-1966; I=1,2,...,5; J=1, 2,...,10.</td>
<td>UN [103]</td>
</tr>
<tr>
<td>PBIJ</td>
<td>Average import price in region J of wheat from country I in the base period of 1964-1966; U.S. $ per metric ton; I=1,2,...,5; J=1,2,...,10.</td>
<td>UN [103]</td>
</tr>
</tbody>
</table>
APPENDIX B: PRELIMINARY OLS ESTIMATION OF THE PER CAPITA WHEAT IMPORT DEMAND EQUATIONS
Table B.1. OLS estimates of the wheat import demand equations, 1962-78

\[ MQ_1 = 19.400 - 9.2532 \frac{P_1}{CPE_1} + 0.3044 \frac{PA_1}{CPE_1} - 4.0875 \times YE_1 \]
\[ (3.31)^a \quad (-2.70) \quad (2.39) \quad (-2.56) \]
\[ MSE^b = 2.261 \quad DW^c = 2.10 \quad R^2 = 0.73 \]

\[ MQ_2 = 98.847 - 52.807 \frac{P_2}{CPE_2} + 1.0651 \frac{PA_2}{CPE_2} - 12.410 \times YE_2 \]
\[ (4.95) \quad (-3.73) \quad (2.57) \quad (-1.76) \]
\[ -1.3273 \times SP_2 - 1 \]
\[ (-2.03) \]
\[ MSE = 21.97 \quad DW = 2.29 \quad R^2 = 0.77 \]

\[ MQ_3 = 30.953 - 0.7352 \frac{P_3}{CPE_3} + 13.603 \times YE_3 - 0.4909 \times Q_3 \]
\[ (3.15) \quad (-0.22) \quad (2.48) \quad (-1.44) \]
\[ MSE = 6.457 \quad DW = 1.07 \quad R^2 = 0.89 \]

\[ MQ_4 = 33.377 - 9.8088 \frac{P_4}{CPE_4} + 0.2968 \frac{PA_4}{CPE_4} - 13.991 \times YE_4 \]
\[ (1.47) \quad (-0.89) \quad (0.78) \quad (-1.73) \]
\[ MSE = 21.86 \quad DW = 1.96 \quad R^2 = 0.54 \]

\[ MQ_5 = 25.389 - 14.163 \frac{P_5}{CPE_5} + 0.04747 \frac{PA_5}{CPE_5} + 40.171 \times YE_5 \]
\[ (5.09) \quad (-2.94) \quad (1.67) \quad (5.25) \]
\[ -3.1722 \times ST_5 - 1 - 0.7011 \times A_5 \]
\[ (-4.31) \quad (-3.28) \]
\[ MSE = 3.596 \quad DW = 2.22 \quad R^2 = 0.95 \]

---

^t-statistics are in parentheses.

^MSE represents mean square error.

^DW represents Durbin-Watson d statistic.
Table B.1. (Continued)

\[ MQ_6 = 8.327 - 3.7960 \left( \frac{P6}{QPE6} \right) + 32.427 \times YE_6 - 1.1578 \times SP_6 \]
\[ (1.70) \quad (1.45) \quad (5.82) \quad (-1.57) \]
\[ -0.3202 \times Q_6 \]
\[ (-2.33) \]
\[ \text{MSE} = 3.005 \quad DW = 2.38 \quad R^2 = .94 \]

\[ MQ_7 = -13.798 + 163.47 \times YE_7 - 0.4999 \times ST_7 \]
\[ (-2.30) \quad (4.96) \quad (-4.22) \]
\[ -0.1115 \times Q_7 - 0.4768 \times A_7 \]
\[ (-1.05) \quad (-2.26) \]
\[ \text{MSE} = 1.220 \quad DW = 1.42 \quad R^2 = .91 \]

\[ MQ_8 = 12.680 - 2.6413 \times P_8 + 0.01655 \times PA_8 - 0.1597 \times Q_8 \]
\[ (4.72) \quad (-2.09) \quad (2.46) \quad (-1.93) \]
\[ +3.8913 \times D_8 \]
\[ (2.63) \]
\[ \text{MSE} = 1.423 \quad DW = 0.99 \quad R^2 = .65 \]

\[ MQ_9 = 38.583 - 6.0245 \times P_9 - 0.7562 \times A_9 \]
\[ (7.17) \quad (-2.36) \quad (-5.98) \]
\[ \text{MSE} = 30.54 \quad DW = 1.95 \quad R^2 = .72 \]

\[ MQ_{10} = 34.709 - 16.090 \times P_{10} - 0.09565 \times SP_{10} - 1 + 28.073 \times D \]
\[ (3.61) \quad (-2.00) \quad (-1.59) \quad (2.76) \]
\[ \text{MSE} = 122.76 \quad DW = 1.53 \quad R^2 = .47 \]
APPENDIX C: CONSTRUCTED YIELD VARIATION INDEX
### Table C.1. Yield variation index for Argentina, Australia, Canada and France, 1961-78^a^

<table>
<thead>
<tr>
<th>Year</th>
<th>Argentina</th>
<th>Australia</th>
<th>Canada</th>
<th>France</th>
</tr>
</thead>
<tbody>
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<td>1961</td>
<td>-4.20</td>
<td>-3.46</td>
<td>-42.26</td>
<td>-10.69</td>
</tr>
<tr>
<td>1962</td>
<td>11.66</td>
<td>6.43</td>
<td>5.48</td>
<td>9.86</td>
</tr>
<tr>
<td>1963</td>
<td>14.59</td>
<td>12.90</td>
<td>27.41</td>
<td>-8.72</td>
</tr>
<tr>
<td>1964</td>
<td>32.44</td>
<td>15.96</td>
<td>-4.61</td>
<td>3.95</td>
</tr>
<tr>
<td>1965</td>
<td>-5.43</td>
<td>-17.04</td>
<td>5.21</td>
<td>3.64</td>
</tr>
<tr>
<td>1966</td>
<td>-14.94</td>
<td>24.56</td>
<td>24.30</td>
<td>-13.41</td>
</tr>
<tr>
<td>1967</td>
<td>-11.30</td>
<td>-31.77</td>
<td>-14.49</td>
<td>7.42</td>
</tr>
<tr>
<td>1968</td>
<td>-31.29</td>
<td>11.34</td>
<td>-6.52</td>
<td>4.60</td>
</tr>
<tr>
<td>1969</td>
<td>-6.25</td>
<td>-9.76</td>
<td>13.10</td>
<td>-0.99</td>
</tr>
<tr>
<td>1970</td>
<td>-8.57</td>
<td>-1.96</td>
<td>6.92</td>
<td>-7.70</td>
</tr>
<tr>
<td>1971</td>
<td>-10.16</td>
<td>-4.64</td>
<td>7.24</td>
<td>0.97</td>
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<tr>
<td>1972</td>
<td>7.76</td>
<td>-31.83</td>
<td>-4.11</td>
<td>15.29</td>
</tr>
<tr>
<td>1973</td>
<td>11.39</td>
<td>4.94</td>
<td>-5.86</td>
<td>10.24</td>
</tr>
<tr>
<td>1974</td>
<td>-5.93</td>
<td>4.37</td>
<td>-18.83</td>
<td>9.68</td>
</tr>
<tr>
<td>1975</td>
<td>7.63</td>
<td>9.20</td>
<td>-3.94</td>
<td>-10.41</td>
</tr>
<tr>
<td>1976</td>
<td>12.44</td>
<td>1.33</td>
<td>9.48</td>
<td>-14.93</td>
</tr>
<tr>
<td>1977</td>
<td>-11.60</td>
<td>-27.53</td>
<td>0.43</td>
<td>-7.36</td>
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<tr>
<td>1978</td>
<td>11.93</td>
<td>37.06</td>
<td>0.09</td>
<td>7.67</td>
</tr>
</tbody>
</table>

^aThe yield variation index is constructed from actual yield of wheat (FAO [24]) and the expected value of the yield, which is obtained by the regressions of yield on time trend.
APPENDIX D: ESTIMATION OF THE PRICE LINKAGE EQUATIONS
Table D.1. Estimated price linkage equations, 1962-1978

<table>
<thead>
<tr>
<th>Dependent variable (PXIJ)</th>
<th>Estimation method</th>
<th>Constant</th>
<th>Export price (PWI/ERI)</th>
<th>Dummy variable (DYR)</th>
<th>DW for OLS or ρ for ALS</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>PX11</td>
<td>ALS</td>
<td>-0.004</td>
<td>1.0219</td>
<td></td>
<td>.382</td>
<td>.95</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-0.0)b</td>
<td>(16.92)</td>
<td></td>
<td>(1.70)</td>
<td></td>
</tr>
<tr>
<td>PX21</td>
<td>OLS</td>
<td>6.948</td>
<td>0.8641</td>
<td></td>
<td>1.78</td>
<td>.93</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.24)</td>
<td>(14.29)</td>
<td></td>
<td>(1.70)</td>
<td></td>
</tr>
<tr>
<td>PX31</td>
<td>OLS</td>
<td>-6.334</td>
<td>1.1587</td>
<td></td>
<td>1.86</td>
<td>.95</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-0.84)</td>
<td>(16.15)</td>
<td></td>
<td>(1.70)</td>
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</tr>
<tr>
<td>PX51</td>
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<td>1.80</td>
<td>.98</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-1.86)</td>
<td>(27.20)</td>
<td></td>
<td>(1.70)</td>
<td></td>
</tr>
<tr>
<td>PX22</td>
<td>ALS</td>
<td>1.562</td>
<td>0.9885</td>
<td></td>
<td>.250</td>
<td>.98</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.42)</td>
<td>(24.66)</td>
<td></td>
<td>(1.06)</td>
<td></td>
</tr>
<tr>
<td>PX32</td>
<td>ALS</td>
<td>-2.203</td>
<td>1.0743</td>
<td></td>
<td>.256</td>
<td>.98</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-0.55)</td>
<td>(28.24)</td>
<td></td>
<td>(1.09)</td>
<td></td>
</tr>
<tr>
<td>PX42</td>
<td>OLS</td>
<td>-3.907</td>
<td>1.0321</td>
<td></td>
<td>1.03</td>
<td>.98</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-1.04)</td>
<td>(27.37)</td>
<td></td>
<td>(1.06)</td>
<td></td>
</tr>
<tr>
<td>PX52</td>
<td>ALS</td>
<td>-4.443</td>
<td>1.0395</td>
<td></td>
<td>.253</td>
<td>.99</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-1.46)</td>
<td>(33.36)</td>
<td></td>
<td>(1.08)</td>
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<tr>
<td>PX23</td>
<td>OLS</td>
<td>-0.938</td>
<td>1.0642</td>
<td></td>
<td>1.82</td>
<td>.97</td>
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<tr>
<td></td>
<td></td>
<td>(-0.20)</td>
<td>(21.32)</td>
<td></td>
<td>(1.07)</td>
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<td>.98</td>
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<td>(30.76)</td>
<td></td>
<td>(1.06)</td>
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<tr>
<td>PX53</td>
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<td>1.1152</td>
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<tr>
<td></td>
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<td>(-5.06)</td>
<td>(66.07)</td>
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<td>(1.05)</td>
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<tr>
<td>PX14</td>
<td>OLS</td>
<td>-12.275</td>
<td>1.2018</td>
<td></td>
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<td>.88</td>
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<td>(-1.14)</td>
<td>(10.39)</td>
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<td>(1.04)</td>
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<tr>
<td>PX24</td>
<td>OLS</td>
<td>0.986</td>
<td>1.0246</td>
<td></td>
<td>139.50(D73)c</td>
<td>1.35</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>(20.14)</td>
<td></td>
<td>(15.90)</td>
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<tr>
<td>PX34</td>
<td>OLS</td>
<td>0.954</td>
<td>1.0031</td>
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<td>102.74(D73)</td>
<td>1.92</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.18)</td>
<td>(19.92)</td>
<td></td>
<td>(10.80)</td>
<td></td>
</tr>
</tbody>
</table>

a Durbin-Watson d statistic if OLS is used, or estimated autocorrelation coefficient if ALS is used.

b t-statistics are in parentheses.

c Dummy variables introduced are indicated in parentheses.
<table>
<thead>
<tr>
<th>Dependent variable (PXIJ)</th>
<th>Estimation method</th>
<th>Constant</th>
<th>Export price (PWI/ERI)</th>
<th>Dummy variable (DYR)</th>
<th>DW for OLS or p for ALS</th>
<th>R²</th>
</tr>
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<tbody>
<tr>
<td>PX44 OLS</td>
<td>3.115 (0.57)</td>
<td>0.9979 (18.04)</td>
<td></td>
<td></td>
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<td>.96</td>
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<td>PX54 OLS</td>
<td>-1.222 (-0.33)</td>
<td>1.0213 (27.19)</td>
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<td>.98</td>
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<td>PX15 OLS</td>
<td>7.263 (1.63)</td>
<td>0.9025 (18.96)</td>
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<td>1.34</td>
<td>.96</td>
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<tr>
<td>PX25 ALS</td>
<td>3.786 (0.54)</td>
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<td>1.4301 (13.25)</td>
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<tr>
<td>PX26 ALS</td>
<td>3.480 (1.11)</td>
<td>1.0729 (31.60)</td>
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<td>PX46 OLS</td>
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<td>PX56 ALS</td>
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<tr>
<td>PX17 ALS</td>
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<td>PX57 OLS</td>
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<td>0.9715 (25.98)</td>
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Table D.1. (Continued)

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<th>Dependent variable (PXIJ)</th>
<th>Estimation method</th>
<th>Constant</th>
<th>Export price (PWI/ERI)</th>
<th>Dummy variable (DYR)</th>
<th>DW for OLS or p for ALS*</th>
<th>R²</th>
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<td>(1.61)</td>
<td>(10.16)</td>
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<td>PX49</td>
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<td>9.796</td>
<td>0.8298</td>
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<td>1.73</td>
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