IMPORT DEMAND FOR FRESH TOMATOES AND ONIONS IN SAUDI ARABIA

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ABSTRACT

Scope and Method of Study:

Currently, subjective estimates for elasticities are used to adjust agricultural trade policies while Saudi Arabia is going through procedures for accession to the World Trade Organization (WTO). An Almost Ideal Demand System model (AIDS), a Rotterdam model (ROT), a Central Bureau of Statistics model (CBS), a National Bureau of Research model (NBR), and a general model were specified to estimate Saudi Arabia's import demand for tomatoes and onions. Symmetry and homogeneity restrictions were tested, and nested tests were conducted to determine which model specifications were most appropriate. Model estimates were used to calculate expenditure, own-price, and cross-price elasticities of demand.

Findings and Conclusions:

Symmetry and homogeneity restrictions were not rejected for any of the five models for onions, but they were rejected for all but two of the models (ROT and NBR) for tomatoes. Nested tests indicated that, of the five models, the general model was most appropriate for both tomatoes and onions. Expenditure elasticities indicate that as consumers increased expenditures on imported onions, most of those expenditures went to onions from India. As expenditures on tomatoes increased, most went to tomatoes from Syria. Own-price elasticities indicate that demand is more elastic for some sources than for others. This suggests that changes in tariffs will affect imports from sources more than others.

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TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

Table | Page

Table Page

LIST OF FIGURES

Figure Page

Figure Page

CHAPTER I

INTRODUCTION

Saudi Arabia has succeeded in increasing its production of crop and animal products as a result of government programs intended to reduce dependency on oil and oil-related commodities. However, the Saudi government has considerably reduced its support for wheat production. This has been due to a short supply of natural water and because, since 1984, wheat production has increased more than enough to achieve self-sufficiency. This has led to an increase in production of other agricultural products. For example, the production of vegetables & melons has increased from 736,368 metric tons in 1980 to 1,546,000 metric tons in 2002 (Table 1, and Figure 1).

Vegetable production (excluding melons) is still less than the production of other agricultural products. More importantly, the rate of increase of vegetable production is less than the Saudi population growth rate of 119% from 1980 to 2001 (Table 2, and Figure 2). This, together with an increasingly open market in Saudi Arabia, has led to an increase in net imports of agricultural products, including vegetables, (Table 3, and Figures 3-5). The imported products include tomatoes, potatoes, and onions from more than fifteen countries including Syria, Lebanon, Jordan, India, Turkey, and Egypt.

Table 1. Domestic Agricultural Production of Vegetables, Fruit, and Cereals.

Year	Production of Vegetables & Melons (Mt)	Production of Fresh Vegetables (Mt)	Production of Fruit excluding Melons (Mt)	Production of Cereals (Mt)
1980	736,368	35,000	466,696	266,238
1981	639,159	60,000	490,495	294,042
1982	1,270,327	262,978	511,568	488,520
1983	1,082,380	180,000	602,712	874,586
1984	1,418,883	430,000	701,115	1,443,643
1985	1,541,806	480,000	726,708	2,187,821
1986	1,444,511	379,676	737,833	2,460,924
1987	1,872,229	600,000	810,713	2,929,420
1988	1,896,185	650,000	831,412	3,692,086
1989	1,933,602	750,000	858,731	3,931,967
1990	2,201,169	975,727	803,890	4,136,772
1991	1,827,129	677,117	833,994	4,574,269
1992	1,977,016	700,064	899,169	4,702,572
1993	2,014,607	695,343	951,390	5,042,521
1994	2,050,944	696,615	987,941	4,859,501
1995	2,317,230	625,536	1,052,988	2,668,863
1996	2,281,918	632,255	1,090,789	1,931,516
1997	2,268,714	608,081	1,150,562	2,338,534
1998	2,244,917	598,450	1,195,247	2,201,566
1999	1,481,000	360,000	1,153,000	2,454,119
2000	1,546,000	362,000	1,189,000	2,131,464
2001	1,546,000	362,000	1,189,000	2,091,200
2002	1,546,000	362,000	1,189,000	2,111,000

Source: FAO Food Balance Sheet.

Table 2. The Population of Saudi Arabia as a Total, % Growth Rate, Rural, Urban, and Agricultural.

Year	Total Population (1,000s)	Growth Rate (%)	Rural Population (1,000s)	Urban Population (1,000s)	Agricultural Population (1,000s)
1980	9,604		3,279	6,325	4,176
1981	10,104	5.21	3,308	6,796	4,144
1982	10,602	4.93	3,324	7,277	4,088
1983	11,111	4.80	3,332	7,779	4,012
1984	11,652	4.87	3,338	8,315	3,922
1985	12,238	5.03	3,347	8,891	3,820
1986	12,879	5.24	3,362	9,517	3,706
1987	13,564	5.32	3,381	10,183	3,573
1988	14,249	5.05	3,393	10,856	3,408
1989	14,874	4.39	3,387	11,487	3,198
1990	15,400	3.54	3,354	12,046	2,940
1991	15,806	2.64	3,291	12,516	2,836
1992	16,114	1.95	3,201	12,912	2,715
1993	16,380	1.65	3,100	13,280	2,588
1994	16,687	1.87	3,005	13,682	2,470
1995	17,091	2.42	2,930	14,161	2,368
1996	17,614	3.06	2,880	14,733	2,283
1997	18,237	3.54	2,851	15,384	2,209
1998	18,930	3.80	2,836	16,088	2,142
1999	19,644	3.77	2,826	16,812	2,074
2000	20,346	3.57	2,815	17,531	2,002
2001	21,028	3.35	2,799	18,232	1,928

Sources: Ministry of Economics and Planning, Kingdom of Saudi Arabia, Department of Statistics. (various issues 1980-2003) Riyadh, Saudi Arabia.

Table 3. Values of Saudi Arabian Imports and Exports of Total Agricultural Products and Vegetable Products (1,000$).

Year	Total Agricultural Product Imports	Total Agricultural Product Exports	Total Agricultural Product Net Imports	Veg Product (Fresh or Dried) Imports	Veg Product (Fresh or Dried) Exports	Veg Product (Fresh or Dried) Net Imports
1980	4,202,408	110,430	4,091,978	1,797	73	1,724
1981	5,034,200	113,065	4,921,135	1,673	52	1,621
1982	5,205,670	97,924	5,107,746	2,058	50	2,008
1983	4,708,210	79,502	4,628,708	2,228	390	1,838
1984	5,236,388	94,169	5,142,219	1,917	224	1,693
1985	3,889,989	108,478	3,781,511	2,220	20	2,200
1986	3,512,276	208,729	3,303,547	1,543	141	1,402
1987	3,694,708	289,172	3,405,536	4,943	22	4,921
1988	3,752,573	391,557	3,361,016	1,149	138	1,011
1989	3,735,805	424,417	3,311,388	1,932	51	1,881
1990	3,960,977	362,174	3,598,803	1,575	187	1,388
1991	4,336,806	458,150	3,878,656	771	38	733
1992	3,662,597	459,109	3,203,488	1,058	13	1,045
1993	3,418,775	472,406	2,946,369	451	1	450
1994	3,123,408	412,020	2,711,388	1,094	4	1,090
1995	4,482,153	456,908	4,025,245	1,697	65	1,632
1996	4,765,706	398,824	4,366,882	1,094	0	1,094
1997	4,893,977	471,908	4,422,069	1,111	0	1,111
1998	4,583,191	466,449	4,116,742	600	45	555
1999	4,516,142	293,496	4,222,646	550	30	520
2000	5,275,175	474,382	4,800,793	4,287	191	4,096
2001	4,656,803	439,491	4,217,312	1,354	173	1,181
2002	5,111,232	532,825	4,578,407	4,260	12	4,248

Source: FAO Trade Yearbook.

Imports represent more than 50% of the total consumption of these vegetables in Saudi Arabia (Table 4).

The increase in the amount of imported vegetables purchased by consumers may be due to three main factors. The first factor may be price variability of these products. The instability of prices may partially relate to the lack of adequate policy in agricultural marketing. The second factor is related to climate. During parts of the year, the domestic market suffers from shortages of locally produced vegetables due to a hot and dry climate in summer and frost and freezing in winter. Finally, consumers may tend to prefer imported vegetables because they are packaged attractively in appropriately sized packages and the vegetables themselves look more appealing to a typical consumer.

Recently, Saudi Arabia has been going through procedures for accession to the World Trade Organization (WTO). Imports are likely to become even more attractive as their price is reduced. Little information currently exists to help policymakers and industry participants understand the effects of reduced trade barriers on vegetable imports.

Purpose and Objectives

The purpose of this research is to understand Saudi Arabian consumers' demand for imported vegetables. Several models are constructed, estimated, and used to test hypotheses regarding consumer preferences for imported vegetables. The estimated elasticities can be used to predict changes in quantities demanded as prices change as well as the effects of taxes and tariffs on quantities demanded. Furthermore, they may

Table 4. Summary Statistics for Expenditure Shares of Saudi Arabian Vegetable Imports and Domestic Production for 1980-2000.

Variable	Mean	Std Dev	Minimum	Maximum.
Onions				
Syria	0.0086495	0.0133001	0.0001422	0.0422194
Lebanon	0.0037993	0.0056943	0.0001187	0.0233464
Jordan	0.0063238	0.0069659	0.0001127	0.0263664
India	0.1798614	0.1045386	0.0438472	0.4164213
Egypt	0.0903580	0.1066639	0.0008551	0.4074944
Turkey	0.2695805	0.1518343	0.0877077	0.5078395
Other Countries	0.1026383	0.0905770	0.0072444	0.2763424
Total Imported	0.6611359	0.2224028	0.2472850	0.8749862
Domestic	0.3388641	0.2224028	0.1250138	0.7527150
Tomatoes				
Syria	0.0378921	0.0553057	0.0000397	0.1755967
Lebanon	0.0051439	0.0065661	0.0001258	0.0278975
Jordan	0.0251266	0.0234532	0.0000475	0.0709066
India	0.0000400	0.0000863	0.0000320	0.0003444
Egypt	0.0116908	0.0076816	0.0039353	0.0322383
Turkey	0.0455790	0.0257752	0.0121572	0.1012680
Other Countries	0.0053641	0.0044892	0.0003971	0.0155146
Total Imported	0.1308365	0.0330383	0.0795210	0.2146876
Domestic	0.8691635	0.0330383	0.7853124	0.9204790

Source: Calculated from Ministry of Economics and Planning, Kingdom of Saudi Arabia, Department of Statistics. (various issues 1980-2000) Riyadh, Saudi Arabia.

increase understanding of the problems of competition that domestic producers in Saudi Arabia have been facing for several decades from imported products.

In this study, the demand system parameters were used to estimate the Marshallian (uncompensated) and Slutsky (compensated) own-price, cross-price, and expenditure elasticities of demand for tomatoes, potatoes, and onions imported from different countries. This will provide information on the level of competition among countries exporting these vegetables to Saudi Arabia. Also, the higher the elasticity of demand for a vegetable, the higher its sensitivity to a tariff, and vice-versa. Representatives of the Saudi government can use this information at WTO meetings when negotiating vegetable tariffs.

CHAPTER II

MARKET FOR IMPORTED VEGETABLES IN SAUDI ARABIA

Introduction

Saudi Arabia's total imports have jumped from just $0.8 billion in 1970 to $31.2 billion in 2001, a 39-fold increase in 32 years (Ministry of Economics and Planning, 2001). This trade may not grow as fast in the next 32 years as it has in the past, but may still increase based on because of current trends in domestic demand and supply.

This pattern of growth in import demand in Saudi Arabia suggests not only opportunity for trade but also for fresh investment for new projects in industry, agriculture and other productive sectors. As far as vegetables are concerned, Saudi Arabia will remain a good market, at least in the next two decades. Saudi Arabian weather is harsh, which causes fluctuation in domestic production. Domestic demand is likely to increase due to the high population growth rate, 3.5% per year (Ministry of Economics and Planning, 2001).

Differences Between Imported and Domestic Vegetables

There are three fundamental differences between imported and domestic vegetables: appearance and grading, taste, and availability throughout the year. With regard to appearance and grading, imported vegetables, which include tomatoes, potatoes, and onions, are packaged attractively in a manner that may facilitate their shipping and handling. Moreover, because of effective and efficient preservation measures, distributors have sufficient time to sell their vegetables in optimum condition without deterioration. In contrast, domestic vegetables suffer from poor grading and packaging because of producers' lack of knowledge. Hence, they spoil easily.

Regarding taste, certain domestic vegetables like tomatoes are perceived to taste far better than imported ones. This situation can be easily explained by the fact that the domestic tomatoes are collected from the field after reaching full maturity whereas the imported products are wrapped and shipped before they are even full maturity.

Finally, domestic vegetables are produced seasonally. Imported vegetables are available to the Saudi consumer throughout the year because of the diversity of the countries exporting to Saudi Arabia.

Vegetable Markets in Saudi Arabia

Economic policy in Saudi Arabia is an open free-trade system (Ministry of Economics and Planning, 2002). Therefore, to improve the market efficiency of commodities and services, and to fulfill the requirements mandated by the WTO, the government avoids direct interference in the market affairs.

The main objective of this study is to analyze import demand by Saudi Arabia for fresh tomatoes and fresh onions. Potatoes are also a major import, but the available data combines both fresh and frozen potatoes in one series. Frozen potatoes are especially important in the fast food industry. Because of the different characteristics of the fresh and frozen potato markets, it was not possible to use this data to analyze demand for fresh potatoes.

There are three major vegetable markets in Saudi Arabia located in three large cities: Riyadh, Jeddah, and Dammam. The biggest one is located in the capital city, Riyadh. This market has two branches: one in the north side of the city called Northern Vegetables Market, and one in the center, called "Otaigah". These locations are owned by the government, and it is important to note that the government does not charge any fees for using its property to sell those commodities.

Northern Vegetable Market

This wholesale market deals primarily in imported potatoes and onions. The imported commodities are carried in trucks to the market to be received by traders who have purchased these products. Sometimes, the products' owners delegate their power to brokers (their representatives) to sell their products. The broker's commissions are approximately between 2.5%-5% percent of the total sale. The owners bear the expenses of the waiting trucks until the completion of the sale. Brokers decide on the sale prices depending on the current market value which depends on supply and demand. Brokers often charge a lower price to their regular high demand customers.

Onions are brought to market with regular trucks that do not have freezers or any refrigerating system. Unlike tomatoes, they are stocked in large quantities with a minimum of 50 bags. Bags of either Red or White onions contain 20 Kg, 15Kg, 10Kg or 5Kg each. Auctioneers sell the minimum limit of 50 bags to owners of super markets, food services providers, or specialists in vegetables and fruits markets.

Otaigah Vegetable Market

According to the Ministry of Agriculture (2000) the Otaigah vegetable and fruit market is one of the largest markets in the Middle East, where almost 30% of the imported and local products are sold. A major section of this market is specialized in selling imported fruits and vegetables. The imported vegetables are transported from the border of Saudi Arabia to the Otaigah market in cooled trucks. Once the products reach the market, they are unloaded and sold by auctioneers in sets of 50 boxes per unit, at 10 kg, 8kg, or 5kg. per box. Buyers are usually distributors or individuals who own large super markets. The sale is on a daily basis, from 5:00-7:00 AM and again from 6:00-8:00Pm. The sale is by auction, with the highest bidder getting the product. The commodities are sold in large quantities.

Vegetable Market Size

Vegetable markets in Saudi Arabia have been growing very fast in recent decades. Such expansion offers opportunities for exporters of vegetables. The total size of the Saudi market may look relatively small because of its small population of 22 million, including about 5 million foreigners, in 2000 (Ministry of Economics and Planning 2002). Notwithstanding its small size, the market has a high level of purchasing power. Saudi citizens have an annual per capita income of $11,670 (Ministry of Economics and Planning 2003), and the population has been increasing at a fast rate over 3.5% per year. An eventual integration of Saudi Arabia into the Gulf Countries Counsel (GCC) is expected to add a new dimension to the Saudi market potential.

Import Tariffs

Effective May 29, 2001, the Saudi Government reduced the general tariff protection rate from 12% to 5% (Ministry of Economics and Planning 2002). Almost all Saudi imports fall into this category, including vegetables. Due to the tariff reduction, prices of most commodities are likely to drop significantly. With such a drop in the tariff rates, exports of various items to Saudi Arabia will increase considerably. Also, re-exports will likely increase, especially since exports to GCC countries will be tariff free.

Import Policies and Procedures

Saudi Arabia has traditionally pursued a liberal trade policy. It has neither quantitative restrictions nor discriminatory tariff or non-tariff barriers. The Saudi Arabian Government believes in the concept of free enterprise and, therefore, does not enter into any form of state trading. The private sector has developed strong and specialized trading organizations. This specialization has encouraged the installation of modern facilities like refrigerated warehouses and use of refrigerated carriers.

The Ministry of Trade and Manufacturing Products assigns a certain type of license or certificate to large companies and corporations in order to be legally allowed to import fruits and vegetables.

When the imported vegetables arrive at the borders, inspectors check them thoroughly to see if they meet the general requirements mandated by authorities and conform to general standards of hygiene and safety. Inspection usually is conducted in two ways. The first one is for products specifically designated for Saudi market. The second is specifically designated for exportation to the neighboring countries in the gulf area, such as Kuwait, United Arab Emirates, Qatar, and Bahrain. However, this second category accounts for no more than 5% of total imported vegetables.

World Trade Organization

Saudi Arabia is currently seeking membership in the WTO. Once Saudi Arabia is admitted, the country's trade regime may become more transparent and more accommodating to non-Saudi businesses. Moreover, the Saudi Arabian leadership has embarked on a wide-range of projects intended to restructure the entire Saudi economy. A number of economic and political reforms are underway that will lay the foundation for a climate more conducive to foreign enterprises. Saudi business practices and laws still favor or give priority to Saudi citizens. Also, Saudi Arabia still has trade barriers, mainly regulatory and bureaucratic practices, which restrict the level of trade.

Joining the WTO is the basic reason why the government has undertaken the reforms and significant progress seems to have already been made in negotiations towards gaining entry. Saudi Arabia will greatly benefit from membership and the necessary changes in the trade regime (King Saud University, 1998). This will include the removal of protectionist barriers that restrict foreigners from operating in key service sectors, and tariff reductions that will help bring about economic expansion. The improved investment climate will inevitably bring competition, which will be beneficial for the economy in the sense that it will increase efficiency. Saudi Arabia may also be entitled to be one of the policy-makers of the global economy, which is essential if Saudi Arabia is to maintain its position in the new world economy.

Saudi Imports: An Overview

The absorptive capacity of the Saudi economy has been steadily improving, despite some fluctuations in GDP dictated by oil price changes. Moreover, the economic potential of large reserves of oil, estimated at one-fourth of world reserves, is definitely promising. The diversification of the economy has been increasing at a satisfactory pace. The productive sectors have become dynamic. The liberal economic policies and new freedoms in the private sector will give a new stimulus to the process of industrialization. This, together with increased privatization, suggests that firms will become more specialized, necessitating more imports as they focus on their comparative advantage.

Plans for the launching of free trade zones and for initiating re-export trade through Jeddah and Dammam ports will ultimately raise Saudi status in the global trade arena especially among GCC countries.

CHAPTER III

LITERATURE REVIEW

Few studies have estimated demand for imported vegetables in Saudi Arabia. Such studies have been done in other countries, and features of those studies will be applied to this one.

Mohammed (1988) estimated consumption demand for thirteen food commodities in Saudi Arabia. The estimations under constant and declining income elasticity models were made, within four groups of commodities using time series data for the 24 year period 1963-1986. Homogeneity and Slutsky restrictions were imposed. The study indicated that food consumption was affected by income level with varying effects among the four commodity groups.

Kahtani (1989) analyzed the complete food commodity demand system for Saudi Arabia with commodity projections and policy applications for wheat. The demand elasticities were estimated within food groups and across groups. The results showed different growth rates in demand for food, and efficiency in transferring income to consumers more than to the producers.

Seale, Sparks, and Buxton (1992) applied the Rotterdam model to international trade in fresh apples. They considered four importing markets important to U.S. apple exports including Canada, Hong Kong, Singapore, and U.K. The utility tree approach was used in which a country first allocates total income between domestic and imported goods. The results indicate that all apple suppliers to these countries should increase apple exports if expenditure for imported fresh apples in these markets increases. The expenditure elasticity was more elastic for U.S. apples in Hong Kong, Singapore, and U.K. markets but was unitary elastic in Canada.

Lee and Brown (1992) investigated the demand relationships among fresh fruit and juices in Canada using the differential approach for the time period 1960 through 1987. The restricted Rotterdam model and the CBS model were estimated using maximum likelihood. The results indicated that if Canadian consumers were to allocate a larger portion of their budgets to the consumption of fresh fruit and juices, expenditure shares on oranges, apples, orange juice, and apple juice would increase. The own-price and cross-price elasticities for apples and apple juice were estimated.

An Almost Ideal Demand System (AIDS) model was used to estimate demand elasticities for beef, mutton, poultry, and fish in Morocco (Brorsen and Mdafri, 1993) Mutton was shown to be a luxury good reflecting Moroccans' preference for mutton. Demand was shown to be more elastic than has been assumed in some past policy analyses.

Yang and Koo (1994) specified the differentiated AIDS model to estimate Japanese import demand for meat including beef, pork, and poultry. Their study provides elasticities by source of meat import for Japan, and the study allowed substitution between domestic and imported meat. Both block separability and aggregation over product sources were rejected at conventional levels of significance. They concluded that using the AIDS model without source differentiation would result in spurious conclusions. They suggested that the source differentiated AIDS model specified in their study would provide more reliable and detailed information about demand behaviors. They found Japanese consumers were not sensitive to import prices, but to total expenditure on meat in making a decision on beef imports.

Al-kheraiji (1994) studied a demand systems analysis of meat consumption in Saudi Arabia using annual data for the period 1968 to 1992. The study was conducted with the Rotterdam system and the AIDS model. The results showed that the compensated own-price elasticities estimated from the linear approximate almost ideal demand system (LA/AIDS) for meat groups were negative while expenditure elasticities indicated that chicken and lamb were luxury goods. The results indicated that using the LA/AIDS models to study these imports was appropriate. The study projected total meat demand, demand for individual meat types, and demand for imported chicken and lamb.

Andayani and Tilley (1997) estimated a restricted, source-differentiated, almost ideal demand system (RSAIDS) for fruit in Indonesia, 1970-1993. In a two-step approach, they estimated a non-source-differentiated (aggregate) AIDS model assuming perfect substitutability, and then they estimated a RSDAIDS model by Seemingly Unrelated Regressions procedure (SUR) considering homogeneity and symmetry. They found that RSDAIDS model provided an excellent explanation of variation in Indonesian fruit import from the U.S. Although the model was useful in their analysis, they recommended updating it by testing for structural change.

Al-Zoom (2000) used a differentiated AIDS Model to analyze the import demand for citrus (orange, mandarin and lemon) in Saudi Arabia. He further analyzed the level of competition and separability between the main sources of importation (Egypt, Jordan, Lebanon, and other countries). In his study he considered imposing the conditions of additivity, homogeneity and symmetry. By applying such conditions to the demand functions, his study showed that the demand for imported oranges was elastic. Also, he found that import demand was affected by income and prices of other commodities. Further, his study showed competition between Egypt, Jordan, and Lebanon. Also, he found that in the orange import market, consumer preferences indicated more bias towards Egypt and Lebanon in comparison to Jordan.

Tiffin and Tiffin (1999) investigated food demand elasticities for United Kingdom by using an AIDS model with demand theory restrictions. The demand for food was found to be both price and expenditure inelastic. The demand for all individual food categories included in the study was inelastic with respect to total household expenditure.

Jacinto and Ukhova (2000) highlighted various advantages associated with the use of the LA/AIDS model. The advantage included the flexibility of functional form, the satisfaction exact aggregation across consumers, the non-linearity of Engel curves, and the estimation by a suitable linear approximation. They used a two-stage model to estimate aggregate and source-specific import demand elasticities for pork in Japan. This approach allows substitution between domestic and imported products yet avoids econometric problems in generating source-specific parameters, using (SUR). They found that imported pork had a relatively low income elasticity reflecting consumer survey results of lower quality rating for imported pork compared with domestic pork. Their study has two implications: (1) pork imports into Japan are constrained both by high protection and by the strong preference of Japanese consumers for domestic pork over imported pork, and (2) the protective structure of the Japanese pork import market makes product quality a stronger determinant in the market share of foreign suppliers than having a competitive advantage based on low prices.

Dameus, Tilley, and Brorsen (2000) applied a Restricted Source Differentiated Almost Ideal Demand System (RSDAIDS) model in their study that provided elasticity estimates of the Caribbean demand for starchy food from the U. S. and the rest of the world. They found that U.S. wheat price policy oriented toward a reduction in the export price of wheat to the Caribbean might increase the U. S. wheat market share in the Caribbean. For wheat and rice, no competition across sources existed. Instead, there was a complementary relationship across sources for each of the two products. They concluded that Caribbean production of starchy staples was insufficient to satisfy domestic consumption. Thus, it appears that imports of starchy foods play a major role in food security in the Caribbean.

Panos et al.(2001) investigated empirically Greek aggregate demand for four major types of wood imports using a flexible CBS model. They estimated own price elasticities for most of the period examined. Fuel wood imports were elastic with respect to expenditures, while timber imports were inelastic. Moreover, their findings on the elasticities of substitution between the types of imports examined suggested that changes in the import price of timber-for-layers offered the highest substitution possibilities. Changes in the import price of unprocessed timber offered the lowest substitution possibilities among wood imports. Over time, changes in the import price of unprocessed wood and processed imports appear to have increased the substitution possibilities between the former and the rest of wood imports. The opposite appears to be true for the import prices of fuel wood and timber-for-layer imports. They mention that their empirical results may be utilized in policy analyses related to forest trade in a number of ways. This would include their use as building blocks in developing trade models or as inputs in measuring the costs and benefits associated with changes in trade or domestic policies related to forest products. They pointed out that individual elasticities measure a commodity's response to price or expenditure changes. Therefore, those measures have the limitation of being only partial measures of change. Elasticities are proved to be not particularly helpful in identifying the change in the quantity demanded when more than one price changes at the same time. However, the differential demand models shown earlier can be readily transformed to analyze demand changes in the presence of simultaneous price (or expenditure) changes.

Al-kahtani and Al-hamoudi (2002) used LA/AIDS to study import and domestic demand for potatoes from exporting countries, including Syria, Lebanon, Egypt, and one domestic, Saudi Arabia, market. They found that increasing expenditures on potatoes by 1% would increase the demand for domestic production by 2%. This is compared with 0.58% and 0.29% for Egyptian and Syrian potatoes, respectively, while potato imports from the rest of the world would decrease by 0.25%. The result illustrated that all Cournot own-price elasticities are negative. Cournot cross-price elasticities between Syria and Egypt and between imports from Egypt and domestic production in the potato market were negative, indicating complementary relationships between potatoes from Egypt and Lebanon. However, the other cross-price elasticities were positive, which indicates a substitute relationship.

Alpay and Koc (1998) studied household demand in Turkey. They used spatial variation in the cost of aggregated commodity bundles across the selected regions as a proxy for their prices. This approach can easily be applied in all developing countries that collect cross-sectional data from households but do not have adequate time series data. Then, they estimated a complete demand system for Turkey. As compared to previous studies estimating only the expenditure elasticities for Turkey, their results were different, in some cases by large amounts. Thus, as expected, the incorporation of prices into the demand analysis is vital not only in getting the price elasticities but also in obtaining reliable estimates of the expenditure elasticities. Until adequate time series data on prices are obtained, their estimates on price elasticities should be very useful in the evaluation of many different government policies. They noted that Deaton (1988) introduced a methodology for using household survey data to estimate the price elasticities by making use of spatial variation in prices. However, its application requires certain conditions on the data which may not always be met, as in the case of Turkey.

Janda, McCluskey and Rausser (2000) studied food import demand in the Czech Republic. They described food import demand and created a set of import demand elasticity estimates. The AIDS demand system approach was used including the economic theory restrictions of homogeneity, symmetry, and negativity by using Maximum Likelihood methods. They estimated the price, cross-price and group expenditure elasticities, and found that all food commodities were normal goods with positive group expenditures.

Schmitz and Seale (2002) studied import demand for disaggregated fresh fruits in Japan using annual data to analyze the import patterns of Japan's seven most popular fresh fruits. This was done by implementing and testing a general differential demand system that nested four alternative import demand specifications. The test rejected the

AIDS and NBR specifications, but did not reject Rotterdam and CBS. The results of the analysis had several implications for exporters of fresh fruits to Japan. If the price of fresh fruit imports were to increase by a certain percentage in the future, grapefruit imports would drop by more than the percentage increase in price.

Edgerton (1995) presented conditions that determine when estimated demand systems automatically satisfy the adding up constraint. He showed that there exist nonlinear demand systems where adding up is allowed, but where it is not automatically satisfied for SLS and SUR estimates. He further showed that unrestricted AIDS is such a system, as are the symmetry restricted form and the excluded variable form of most demand models. In these situations it is possible to test if the model satisfies the adding up condition.

Malaga and Williams (2000) used the Barten approach to select demand system specification for U.S. and Mexican fresh vegetable demand. The Rotterdam model was found the most appropriate formulation for U.S. and Mexican demand systems, both in winter and summer. They found that growing imports of produce from Mexico and rapid gains in production efficiencies have kept U.S. fresh vegetable prices declining in real terms in recent years. An important structural characteristic of fresh vegetable markets in the U.S. and Mexico is the seasonality of production and trade.

The authors note that a demand system approach usually incorporates all the restrictions of modern consumer demand theory into a single model to ensure that consumer behavior in the model is consistent with theory. Unfortunately, even when the demand system approach is used, theory does not provide much information about the "true" form of the demand functions. Several approaches have developed specifications that approximate the true form and allow some of the theoretical properties of demand to be imposed or tested, the most common of which are the AIDS and the Rotterdam model.

The Barten model likelihood ratio tests indicated rejection of the AIDS model, but failed to reject the Rotterdam model. In the case of Mexico in both seasons, both AIDS and Rotterdam systems were rejected except for the summer Rotterdam model. The study results suggest that the Rotterdam model is the most appropriate demand system for estimating fresh vegetable demand parameters for both the winter and summer seasons in both the U.S. and Mexico.

Although Hicksian, Marshallian and expenditure elasticities were found to be within expected ranges, they exhibited strong seasonal differences in many cases. For example, cucumber and bell pepper own-price elasticities displayed substantial seasonal differences even though tomato and squash own-price elasticities are about the same in fall-winter and spring-summer seasons. Except for tomatoes, expenditure elasticities are all above one suggesting that most fresh vegetables might be considered luxury goods. The test for weak separability suggests that onions are separable and thus do not belong to the "salad vegetable" demand system. Finally, the likelihood test results implied that exogeneity of total expenditures cannot be assumed. The parameters of the Rotterdam model would be biased and inconsistent if the correlation of total expenditures and the disturbance terms were not taken into account.

Alsultan (2002) found that the CBS model was the best model for analyzing imported agricultural products in Saudi Arabia under eight categories, one of which was fresh and processed vegetables and fruit. He calculated expenditure elasticities at 0.835 and own-price elasticity at -0.078.

These studies estimated demand systems for several countries using various methods and techniques. In recent years Saudi Arabia's agricultural policy has changed due to a water shortage and a shortage of agricultural labor, especially for labor-intensive vegetable products. More imports have been necessary to cover the growing demand for vegetables. By using these studies and methods, mentioned above, this study will investigate this demand and try to draw implications for vegetable import policy.

CHAPTER IV

DEMAND THEORY

Introduction

Probably the most straightforward approach to estimating a demand system is to specify a system of demand equations.

Demand Equations

The objective of the consumer is to maximize utility, $U(q)$, subject to a budget constraint. If $U(q)$ is twice continuously differentiable, the Hessian matrix of $U(q)$ is symmetric and it is possible to obtain a Marshallian demand function (Varian, 1992, Pollak, and Wales, 1992), $q = q(m, p)$, where q is a vector of commodities consumed, m is known budget, and p is price vector, so $U(q)$ reaches a maximum subjective to $p'q = m$:

$$MAX \qquad U = U(q) \qquad s.t \qquad p'q = m \tag{1}$$

We can use the Lagrange multiplier function to optimize, such that:

$$L(q, \lambda, p, m) = U(q) - \lambda(p'q - m) \tag{2}$$

where L is the Lagrangian function, and λ is the Lagrangian multiplier, where $\frac{\partial L}{\partial m} = \lambda$.

The necessary first order conditions are:

$$\frac{\partial L(q,\lambda,p,m)}{\partial q} = U_q - \lambda p = 0 \quad \Rightarrow \quad U_q = \lambda p \tag{3}$$

$$\frac{\partial L(q,\lambda,p,m)}{\partial \lambda} = m - p'q = 0 \quad \Rightarrow \quad p'q = m \tag{4}$$

Since the marginal utilities are assumed to be positive, and prices are strictly positive, the Lagrange multiplier must be positive.

The sufficient second order condition for the maximum is:

$$\frac{\partial^2 L(q,\lambda,p,m)}{\partial q \partial q} \text{ p } 0, \tag{5}$$

which implies strict quasi-concavity of utility, (strict convexity of the iso-utility curves). That means $|\bar{H}|$ f 0, where $|\bar{H}|$ the determinant of the Hessian matrix. Assuming a quadratic utility function, it can be shown that a unique solution exists for $q = q(m,p)$ and for the Lagrange multiplier λ:

$$\lambda^* = \lambda(m,p) = \frac{U_q . q^*}{m}, \tag{6}$$

where $q^* = q(m,p)$ is a vector of quantities of commodities consumed that satisfies the first and second-order conditions of the consumer's maximization problems.

We can write the differential of (3) and (4) such that:

$$\frac{\partial^2 U(q^*)}{\partial q \partial p'} dq - \lambda^* dp - p d\lambda = 0 \tag{7}$$

$$-dm + p'dq + q^* dp = 0 \tag{8}$$

or we can write as a matrix notation: $$\begin{bmatrix} H^* & p \\ p' & 0 \end{bmatrix} \begin{bmatrix} dq \\ -d\lambda \end{bmatrix} = \begin{bmatrix} 0 & \lambda^* I \\ 1 & -q^* \end{bmatrix} \begin{bmatrix} dm \\ dp \end{bmatrix} \tag{9}$$

Where (H^* is the Hessian matrix of the utility $U(q^*)$, $H^* = \dfrac{\partial^2 U(q)}{\partial q \partial q}$,

Then $$dq = \frac{\partial q_i}{\partial m} dm + \frac{\partial q_i}{\partial p_i} dp \qquad (10)$$

$$-d\lambda = -\left(\frac{\partial \lambda}{\partial m}\right) dm - \left(\frac{\partial \lambda}{\partial p_i}\right) dp \qquad (11)$$

or in matrix notation: $$\begin{bmatrix} dq \\ -d\lambda \end{bmatrix} = \begin{bmatrix} q_m & q_p \\ -\lambda_m & -\lambda_p \end{bmatrix} \begin{bmatrix} dm \\ dp \end{bmatrix} \qquad (12)$$

Then the vector of marginal income is $q_m = \dfrac{\partial q_i}{\partial m}$, the matrix of marginal price of consumption is $q_p = \dfrac{\partial q_i}{\partial p_j}$, would be considered that the diagonal element of the matrix, q_p, are own price sensitivities, whereas the off-diagonal elements are the cross-price sensitivities, $\lambda_m = \dfrac{\partial \lambda}{\partial m}$, and $\lambda_p = \dfrac{\partial \lambda}{\partial p_i}$.

Combining (9) and (12) given $$\begin{bmatrix} H^* & p \\ p' & 0 \end{bmatrix} \begin{bmatrix} q_m & q_p \\ -\lambda_m & -\lambda_{p'} \end{bmatrix} = \begin{bmatrix} 0 & \lambda^* I \\ 1 & -q^* \end{bmatrix} \qquad (13)$$

it is possible to prove that $q = q(m, p)$ is continuously differentiable if and only if (Resa, 2003).

$$\begin{vmatrix} \dfrac{\partial^2 U(q^*)}{\partial q \partial q'} & p \\ p' & 0 \end{vmatrix} = \begin{vmatrix} H^* & p \\ p' & 0 \end{vmatrix} \neq 0 \qquad (14)$$

$$\left|H^*\right| = \begin{vmatrix} \dfrac{\partial^2 U(q^*)}{\partial q \partial q'} & U_q \\ U_{q^*} & 0 \end{vmatrix} \neq 0 \qquad (15)$$

The property of differentiability holds if the Hessian matrix of the utility function is non-singular. It can be shown that if $U(q)$ is assumed to have a decreasing marginal rate of substitution (MRS) then H^* is non-singular. Therefore if $U(q)$ has a diminishing MRS, the demand equation is continuously differentiable.

Since H^* is a symmetric matrix, it follows that $\begin{vmatrix} Z & q_m \\ q'_m & -\lambda_m \end{vmatrix} \equiv \begin{vmatrix} H^* & p \\ p' & 0 \end{vmatrix}^{-1}$ (16)

is also symmetric.

Substituting (16) into (13) give $\begin{bmatrix} q_m & q_p \\ -\lambda_m & -\lambda_{p'} \end{bmatrix} = \begin{bmatrix} q_m & \lambda^* Z - q_m q^* \\ -\lambda_m & \lambda^* q'_m + \lambda_m q^* \end{bmatrix}$ (17)

Or, rewriting (16) as:

$$\begin{vmatrix} H^* & p \\ p' & 0 \end{vmatrix} \begin{vmatrix} Z & q_m \\ q'_m & -\lambda_m \end{vmatrix} = \begin{vmatrix} I & 0 \\ 0' & 1 \end{vmatrix} = |I| \tag{18}$$

where I is the identity matrix.

So $\quad H^* Z + p q_{m'} = I \quad$ or $\quad Z = H^{*-1} - H^{*-1} p q_{m'}$ (19)

and $\quad H^* q_m - \lambda_m p = 0 \quad$ or $\quad q_m = \lambda_m H^{*-1} p$ (20)

and $\quad p'Z = 0'$ (21)

which implies homogeneity meaning that substitution effects are in fact a reallocation of goods without changing the overall level of consumption. Therefore only the relative price changes are important for substitution effects. the property of adding up is illustrated by,

$$p' q_m = 1 \tag{22}$$

All prices multiplied by their respective propensity to consume sum up to one (i.e. a weighted sum of budget elasticities of demand).

From (19) and (20):

$$Z = H^{*-1} - \frac{1}{\lambda_m} q_m q_{m'} \quad \text{since} \qquad p = \frac{q_m H^*}{\lambda_m} \tag{23}$$

which implies that Z is symmetric, because of H^* is symmetric, and we knew that Hessian matrix has negative diagonal elements which means that indifference curves are convex (see (5)).

From (12) we get:
$$dq = q_m dm + q_p dp \tag{24}$$

By partially substituting (17) into (24) we get

$$dq = q_m dm + (\lambda^* Z - q_m q^*) \; dp \tag{25}$$

Then (25) becomes:

$$dp = q_m (dm - q^* dp) + \lambda^* Z dp \tag{26}$$

Substituting (23) into (26) gives:

$$dq = q_m (dm - q^* dp) + \lambda^* \left(H^{*-1} - \frac{1}{\lambda_m} q_m q_{m'} \right) dp \tag{27}$$

This is the structural form of the (general) demand system where the first term is attributed to the income effect and the second term takes the substitution effect into account.

The substitution effect, due to Hicks and Allan, is given by $\lambda^* Z dp$

By using (17) we can show:

$$q_p = \lambda^* Z - q_m q^* \tag{28}$$

or

$$\lambda^* Z = q_p + q_m q^* \tag{29}$$

The Hicksian demand function is equal to a Marshallian function that is compensated for the change in real income (such that the original utility level is attained).

Combining (28) and (29) we get:

$$\lambda^{*}Z = q_p + q_m q^{*} \quad \Rightarrow \quad \lambda^{*}Z = \lambda^{*}\left(H^{*-1} - \frac{1}{\lambda_m} q_m q_{m'} \right) \tag{30}$$

And thus the second term of (27) represents the substitution effect. Moreover, if interested in separating the effects of price and expenditure change, we can invert the utility unction, $U\left(q_i(p_i, m)\right)$, to be indirect utility function, $\psi(p_i, m)$. This gives the Marshallian demand function such as:

$$q_i(p_i, m) = -\frac{\partial\psi/\partial p_i}{\partial\psi/\partial m}, \qquad \text{for i=1...n}, \tag{31}$$

where q_i is a quantity demanded, p_i is the price of q_i, m is expenditure, $q_i(p_i, m)$ is the Marshallian demand, $\psi(p_i, m)$ is indirect utility function. This expression is usually known as Roy's identity (Varian, 1992).

Contemporary economic literature contains some articles using demand system models. There are four different representations of the consumer's preferences that are dual in the sense that they provide identical information about the consumer's preferences. These four representations are the utility function, the indirect utility function, the cost (or expenditures) function and the distance function (Deaton and Muellbauer 1980). First of all, we should review the main restrictions in demand functions.

Elasticities

The literature on price demand focuses on how price changes influence both the decisions of whether or not to consume and how much to consume. The responsiveness of demand to price changes is measured by the price elasticity of demand, which is defined as the percentage change in demand resulting from a one percent change in price. Economic theory predicts that demand and price changes move in opposite directions, so the numerical measure of price elasticity of demand is expected to be negative.

Economists frequently make use of percentage relationships, which are independent of the size of units used to measure price and quantity, to study the impact that a given change in price will have on different commodities. The most common of these relationships are the concepts of own price elasticity, cross–price elasticity and income elasticity of demand (Nicholson, 1998).

Own-price Elasticity

Own-price elasticity of demand expresses the percentage change in quantity demanded associated with a given percentage change in price of the same commodity.

$$E_p = \left(\frac{\partial q}{\partial p}\right)\left(\frac{p}{q}\right) \tag{32}$$

In general the elasticity of demand for a good depends to a large extent on how many close substitutes it has (Varian, 1999).

Cross-price Elasticity

Cross-price elasticities of demand measure how the quantity purchased of one commodity responds to changes in the price of another commodity. Positive cross-elasticities of demand are associated with substitutes, and negative elasticities are associated with complements.

$$E_{ij} = \left(\frac{\partial q_i}{\partial p_j}\right)\left(\frac{p_j}{q_i}\right) \quad \text{since } i \neq j \tag{33}$$

Income Elasticity of Demand

Income elasticity of demand measures how a consumer responds in the consumption of a good, given a change in the income of that consumer (Gisser 1981). Goods with positive income elasticities of demand are defined as normal goods. Further, if the elasticity is greater than one the good is defined as a luxury good, if it is less than one, it is defined as a necessity good. If the income elasticity of demand is negative the good is defined as an inferior good. In general we can defined income elasticity as the relative change in consumption of a goods over the relative change in income, or such as:

$$E_m = \left(\frac{\partial q}{\partial m}\right)\left(\frac{m}{q}\right) \tag{34}$$

Restrictions in demand functions

The theoretical properties of the Marshallian (uncompensated) and Hicksian (compensated) demand functions usually incorporate all the restrictions of consumer demand theory to ensure that consumer behavior in the model is consistent with the theory. The demand function's restrictions are adding up, homogeneity, symmetry, and negativity.

Adding up

The adding up restriction follows from the linearity of the budget constraint and the monotonicity assumption of preferences. It implies that the total value of both Hicksian and Marshallian demand functions must equal total expenditure in any period. In other words, the budget constraint must hold.

$$m = \sum_{i=1}^{n} p_i h_i \left(p,u\right) = \sum_{i=1}^{n} p_i q_i \left(p,m\right) \tag{35}$$

where m is the budget, or total expenditure, for the *ith* commodity, $h(p,u)$ is Hicksian demand, $q(p,m)$ is the Marshallian demand, p is a vector prices of commodity i, u is a utility of consume i.

Homogeneity

The Marshallian demand function is homogenous of degree zero in total expenditure and prices, while the Hicksian (compensated) demand function is homogenous of degree zero in prices. If we change all prices and total expenditure in the Marshallian demand by the same proportion t for example, neither the budget constraint nor the utility function changes. This implies that a proportional rise in all prices and expenditure has no effect on demand.

$$h_i(tp,u) = h_i(p,u) \quad \text{And,} \tag{36}$$

$$q_i(tp,tm) = q_i(p,m) \qquad t > 0 \quad \text{Since} \quad t^0 = 1 \tag{37}$$

This restriction implies that the sum of the own and cross-price elasticities and the expenditure elasticity for a particular commodity is zero.

$$E_{ii} + E_{ij} + E_{im} = 0 \tag{38}$$

where: E_{ii} = own-price elasticity, E_{ij} = cross-price elasticities, E_{im} = expenditure elasticity.

This condition implies that the substitution effect and the income effect of an own–price change must be consistent with the cross-price and income elasticities for the commodity.

Symmetry

Symmetry indicates how cross-elasticities are related. The cross-price derivatives of the Hicksian demands are symmetric, that is,

$$\frac{\partial h_i(u,p)}{\partial p_j} = \frac{\partial h_j(u,p)}{\partial p_i} \tag{39}$$

Negativity

The $(n \times n)$ matrix formed by the elements $\partial h_i / \partial p_j$ is negative semi-definite, due to expenditure being concave in prices. This matrix is also called the substitution or Slutsky matrix. This implies that the diagonal elements of the substitution matrix are non-positive $\partial h_i / \partial p_j \leq 0$, which is necessary but not sufficient for negativity.

Demand Systems

One type of demand system is a demand function derived from utility maximization (Pollak and Wales 1992). This approach to demand systems estimation has been widely applied by economists (Houthakker, 1960). A second type is a linear expenditure system, which is derived from a utility function suggested by Klein and Rubin (1947-1948). This is still common today, such as:

$$\ln q_{it} = \alpha_i + \sum_j e_{ij} \ln p_{jt} + e_i \ln m_t \qquad \text{(single equation)} \qquad (40)$$

where q_{it} is the quantity consumed of good i at the time t, p_{jt} is the price of good j at time t and m_t is the expenditure at time t,

$$e_{ij} = \frac{\partial \ln q_{it}}{\partial \ln p_{jt}}, \text{ (Cross-price elasticity),}$$

$$e_i = \frac{\partial \ln q_{it}}{\partial \ln m_t}, \text{ (Expenditure elasticity).}$$

The Rotterdam System

The Rotterdam model (Theil, 1965; and Barten 1993) was the first attempt to address some problems in the linear expenditure system. The demand equations are in budget share form and satisfy the adding up condition automatically. The symmetry and homogeneity restrictions implied by consumer theory may be expressed as linear functions of the estimated parameters. The Rotterdam model can be expressed as:

$$w_i d \ln q_i = b_i d \ln Q + \sum_j c_{ij} d \ln p_j \qquad (41)$$

Where: w_i is the average budget share of good i, $w_{it} = \frac{p_{it}q_{it}}{m}$, p_i is the price of good *i*, q_i is the quantity of good i, b_i , and c_{ij} are demand parameters, such that, $b_i = w_{it}e_i = p_{it}\frac{\partial q_{it}}{\partial m_t}$ b_i is the marginal budget share of good i, $b_i = p_i\left(\frac{\partial q_i}{\partial m}\right)$, c_{ij} is the compensated price effect, $c_{ij} = \left(\frac{p_i p_j}{m}\right)s_{ij}$, $w_i = (w_{it} + w_{i,t-1})/2$, $d\ln q_i = \ln\left(\frac{q_{it}}{q_{i,t-1}}\right)$,

$$d\ln Q_t = d\ln m_t - \sum_j w_{jt} d\ln p_{jt} + \sum_j w_{jt} d\ln q_{jt}, \tag{42}$$

If we consider Barten's General Demand Model we can say: $d\ln Q$ is an index number (Divisia volume index) which is equal to the summation of all equations weighted by their average share, such as:

$$d\ln Q_t = \sum_i w_{it} d\ln q_{it}, \tag{43}$$

$$c_{ij} = w_{it}e_{ij} = \frac{p_{it}p_{jt}s_{ij}}{m_t}, \quad d\ln p_i = dp_i/p_i, \quad d\ln q_i = dq_i/q_i$$

s_{ij} is the *ij* element of the Slutsky substitution matrix, e_i is the expenditure elasticity for good i, and e_{ij} is the compensated cross-price elasticity. The raw form of the Slutsky equation is:

$$s_{ij} = \frac{\partial h_i}{\partial p_j} = \frac{\partial q_i}{\partial p_j} + q_j\frac{\partial q_i}{\partial m} \tag{44}$$

The adding up restrictions imply that: $\sum_i b_i = 1$ (Engel aggregation) where b_i is the budget share of commodity *i*, and $\sum_i c_{ij} = 0$ (Cournot aggregation).

One equation from the demand system must be omitted in order to avoid singular variance-covariance matrix. Finally, the symmetry and homogeneity restrictions are specified as functions of the parameters in the Rotterdam system such as:

$$\text{Symmetry} \quad c_{ij} = c_{ji}$$

$$\text{Homogeneity} \quad \sum_j c_{ij} = 0$$

Part of the attraction of using the Rotterdam specification comes from its generality in the sense that it does not assume any specific form of the underlying consumer preferences (Tridimas, 2001), so this model has been used widely in applied research to test the empirical validity of the restrictions of demand theory. The Rotterdam model might describe how the approach to demand analysis can be applied in marketing (Kenneth and Selvanathan 1988).

Almost Ideal Demand System (AIDS)

The AIDS model is derived from an expenditure function, representing the price independent generalized logarithmic preference (Deaton and Muellbauer 1980). For the source differentiated AIDS model, the expenditure function is rewritten to approximate the importer's behavior that differentiates goods from different origins (Yang and Koo 1994; and Stone 1954).

Deaton and Muellbauer (1980) have derived the AIDS model which is:

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln p_j + \beta_i \ln\left(m/P^*\right) + \varepsilon_i \tag{45}$$

where w is budget share, $w_i = p_i q_i / m$, α, β, and γ are demand parameters, i denote goods and, j sources of goods. Good i may be imported from different origins, (Yang and

Koo, 1994). ε is the stochastic error term distributed as $i.i.d(0,\Omega)$, P^* is price index defined by:

$$\ln P^* = \alpha_0 + \sum \alpha_k \ln p_k + \frac{1}{2}\sum_k \sum_l \gamma_{kl} \ln p_k \ln p_l \qquad (46)$$

since the price index (P^*) in the share equation (45) is nonlinear and provides difficulties in estimation, Stone's index is used as a linear approximation (LA/AIDS) suggested by Deaton and Muelbauer. The advantages of using the LA/ AIDS are represented in the literature are flexibility of functional form; satisfying exact aggregation across consumers; non-linearity of Engel curves; and estimation by a suitable linear approximation (Jacinto and Ukhova 2000).

Stone's index in this extension is ($\ln P^* = \sum_k w_k \ln p_k$). However, this index causes a simultaneity problem since the expenditure share in the index, w_{ih}, is also the dependent variable. To avoid this, the lagged share (Eales and Unnevehr, 1988) or the average share (Haden, 1990) has been used (Yang and Koo, 1994). However, $d\ln m = d\ln p + d\ln Q$ By taking the total differential for equation (45) we obtained:

$$dw_i = \beta_i d\ln Q + \sum_j \gamma_{ij} d\ln p_j \qquad (47)$$

The total differential of budget share is:

$$d\ \ln w_i = d\ \ln p_i + d\ \ln q_i - d\ \ln P - d\ \ln Q$$

$$dw_i = w_i(d\ln p_i + d\ln q_i - d\ln m) \qquad (48)$$

or $$dw_i = w_i(d\ \ln p_i + d\ \ln q_i - d\ \ln P - d\ \ln Q)$$

and from (47) and (48) and based on Deaton and Muelbauer's suggestion of substituting the Divisia Price index $\sum w_i d \ln p_i$ for $d \ln P^*$, the differential AIDS model can be derived as:

$$w_i d \ln q_i = (\beta_i + w_i) \; d \ln Q + \sum_j \{ \; \gamma_{ij} - w_i (\delta_{ij} - w_j) \; \} \; d \ln p_j \tag{49}$$

where δ_{ij} is the Kronecker delta equal to unity if $i = j$ and zero otherwise (Barten, 1993).

With the constants satisfying the following restrictions:

$$\sum_i (\beta_i + w_i) = 0 \qquad \text{(Engel aggregation)} \tag{50}$$

$$\sum_i \gamma_{ij} - w_i(\delta_{ij} - w_j) = 0 \qquad \text{j =1,2,….,n (Cournot aggregation)} \tag{51}$$

$$\sum_j \gamma_{ij} - w_i(\delta_{ij} - w_j) = 0 \qquad \text{i =1,2,….,n (Homogeneity)} \tag{52}$$

$$\gamma_{ij} - w_i(\delta_{ij} - w_j) = \gamma ji - w_i(\delta_{ij} - w_j) \quad \text{(Symmetry)} \tag{53}$$

This parameterization of the model imposes a restriction that the difference between the marginal and the actual budget shares remains constant over the sample period.

Marshallian and Hicksian elasticities are computed from the estimated parameters of the linear approximation of the AIDS model as (Brorsen and Mdafri, 1993):

$$\varepsilon_{ii} = -1 + \gamma_{ii} / w_i - \beta_i \tag{54}$$

$$\varepsilon_{ij} = \gamma_{ij} / w_i - \beta_i (w_j / w_i) \tag{55}$$

$$\delta_{ii} = -1 + \gamma_{ii} / w_i + w_i \tag{56}$$

$$\delta_{ij} = \gamma_{ij} / w_i + w_j \tag{57}$$

where the ε's are Marshallian elasticities, and δ's are Hicksian elasticities.

$$\eta_i = 1 + \beta / w_i \tag{58}$$

where the η_i are expenditure elasticities.

CBS Model

The CBS (Central Bureau of Statistics) model is a hybrid of the AIDS and Rotterdam systems (Keller and Driel, 1985). The quantity coefficients in Rotterdam model are derived as:

$$w_i = \alpha_i + \beta_i \ln m \tag{59}$$

To derive the marginal shares implied by Working model, one multiplies (59) by m and differentiates with respect to m to get:

$$b_i = p_i \left(\partial q_i / \partial m\right) = \alpha_i + \beta_i (1 + \ln m) \tag{60}$$

$$b_i = w_i + \beta_i \tag{61}$$

Replacing b_i in Rotterdam model by (61) gives the CBS Model

$$w_i d \ln q_i = (\beta_i + w_i) \ d \ln Q + \sum_j c_{ij} d \ln p_j \tag{62A}$$

we can rewrite it:

$$w_i (d \ln q_i - d \ln Q) = \beta_i d \ln Q + \sum_j^n c_{ij} d \ln p_j \tag{62B}$$

where $i = 1,...,n$ goods with q_i, p_i, and $w_i = \frac{w_{it} + w_{it+1}}{2}$ denoting the quantity, price, and average expenditure share of the i^{th} good, respectively. Also, β_i and cij are parameters and $d \ln Q = \sum_i^n w_i d \ln q_i$ which is an index number (Divisia volume index) denoting changes in real expenditures. The marginal budget share, $(\beta_i + w_i)$, of the i^{th} commodity is the proportion of a unit increase in real expenditure allocated to that commodity (Panos and Vakrou 2001). The parameters c_{ij} are the compensated prices effects (Slutsky terms). The following restrictions satisfy demand theory.

$$\sum_i \beta_i = 0 \qquad \text{(Engel aggregation)} \qquad (63)$$

$$\sum_i c_{ij} = 0 \quad j = 1,2,\ldots,n \qquad \text{(cournot aggregation)} \qquad (64)$$

$$\sum_j c_{ij} = 0 \quad i = 1,2,\ldots,n \qquad \text{(Homogeneity)} \qquad (65)$$

$$c_{ji} = c_{ij} \qquad \text{(Symmetry)} \qquad (66)$$

The expenditure, compensated, and uncompensated cross-price elasticities, η_i, ξ_{ij}, ε_{ij}, respectively (in the case of i = j the latter two are own-price elasticities) for the ith good of CBS model are calculated as

$$\eta_i = \frac{\beta_i}{w_i} + 1, \quad \varepsilon_{ij} = \frac{c_{ij}}{w_i}, \quad \xi_{ij} = \varepsilon_{ij} - \eta_i w_i$$

NBR Model

The National Bureau of Research (NBR) created another hybrid of the AIDS and Rotterdam model systems by substituting $(\delta_{ij} - w_i)$ for β_i in the AIDS model, (Neves, 1994). The model can be expressed as:

$$w_i d \ln q_i = b_i d \ln Q + \sum_j \gamma_{ij} d \ln p_j - \sum_j w_i \left(\delta_{ij} - w_j\right) \, d \ln p_j \qquad (67A)$$

We can rewrite it so that the RHS (independent variables), is the same as the rest of the models such as:

$$dw_i - w_i d\ln Q = \beta_j d\ln Q + \sum_j \gamma_{ij} d\ln p_j \qquad (67B)$$

This model has the Rotterdam income coefficients and the AIDS price coefficients as parameters, with the parameters satisfying the following restrictions:

$$\sum_i b_i = 0 \qquad \text{(Engel aggregation)} \qquad (68)$$

$$\sum_i \gamma_{ij} - w_i(\delta_{ij} - w_j) = 0 \qquad j = 1,2,\ldots,n \qquad \text{(cournot aggregation)} \qquad (69)$$

$$\sum_j \gamma_{ij} - w_i(\delta_{ij} - w_j) = 0 \qquad i = 1,2,n \qquad \text{(Homogeneity)} \qquad (70)$$

$$\gamma_{ij} - w_i(\delta_{ij} - w_j) = \gamma ji - w_i(\delta_{ij} - w_j) \qquad \text{(Symmetry)} \qquad (71)$$

These four models, ROT, AIDS, CBS, and NBR have the same left-hand side variable $w_i d\ln q_i$ and right-hand side variables $d\ln Q$ and $d\ln p_j s$. These models can be considered as four different ways to parameterize a general model; marginal budget shares are assumed to be constant in the Rotterdam and the NBR models but variable in the AIDS and CBS models. The Slutsky terms are considered to be constants in the Rotterdam and CBS and variable in the AIDS and NBR.

In this study, demand for imported fresh tomatoes and fresh onions in Saudi Arabia is analyzed. Each vegetable demanded by the market is allocated into imports from six main foreign suppliers, including Syria, Lebanon, Jordan, India, Turkey, Egypt, and a group of countries aggregated. The system is estimated using the AIDS, CBS, NBR, and Rotterdam models, as well as a general model. The general model is used to test which one of the four demand systems, if any, is most appropriate for each commodity.

General Demand System

The four models mentioned above (AIDS, CBS, NBR, and Rotterdam) are not nested. McAleer (1983) and Barten (1993) derived a general demand system that nests all four. Lee, Brown, and Seale (1994) present the following general system:

$$w_i d \ln q_i = \theta_i d \ln Q + \eta_1 w_i d \ln Q + \sum_j c_{ij} d \ln p_j - \eta_2 \sum_j w_i \left(\delta_{ij} - w_j\right) \, d \ln p_j + \varepsilon_i \quad (72)$$

The model parameters are θ_i and c_{ij} , ηs are nesting parameters, ε is the stochastic error term distributed as $i.i.d\,(0,\Omega)$. The values that η_1 and η_2 take on determine the compatibility of the data with the four nested demand systems. That is, if $\eta_1 = \eta_2 = 0$ the general model becomes the Rotterdam. When $\eta_1 = 1$ and $\eta_2 = 0$, the CBS model results. When $\eta_1 = \eta_2 = 1$ the AIDS model results, and when $\eta_1 = 0$ and $\eta_2 = 1$, the NBR model results.

The parameters are restricted to satisfy the following:

$$\sum_i \theta_i = 1 - \eta_1 \qquad \text{(Engel aggregation)} \qquad (73)$$

$$\sum_i c_{ij} = 0 \qquad j = 1,2,\ldots,n \qquad \text{(Cournot aggregation)} \qquad (74)$$

$$\sum_j c_{ij} = 0 \qquad i = 1,2,\ldots,n \qquad \text{(Homogeneity)} \qquad (75)$$

$$c_{ij} = c_{ji} \qquad \text{(Symmetry)} \qquad (76)$$

Estimation

In order to choose the best model for analyzing demand for vegetables in Saudi Arabia, a general model that includes the AIDS, Rotterdam, CBS, and NBR models as special cases is estimated and the specification most closely fitting the data is selected. The Barten technique artificially nests four versions of differential demand systems (ROT, AIDS, NBR, and CBS) in a more general model using the Variable Addition Method of McAleer (1983). The resulting demand system will enable policymakers and firms to more appropriately assess the effects of changes in trade (Alsultan, 2002) among the alternative sources (Andayani and Tilley, 1997).

Since quantities and prices of vegetables traded in competitive markets are determined simultaneously, implying that prices are endogenous, parameter estimates are biased. Prices of imported commodities are calculated by dividing values of imports by the quantities imported of the same commodity as proxy of import prices, as Yang and Koo (1994) did.

The SAS Seemingly Unrelated Regressions (SUR) procedure was used to estimate the import demand systems. This procedure provides more efficient estimation relative to OLS when contemporaneous correlation exists which will give biased and inconsistent estimates (Greene, 2000; Kennedy, 1998). By using SUR, the parameters of the model are estimated jointly. When homogeneity and symmetry are imposed on a demand system, one equation from the system is dropped in order to avoid matrix singularity. The parameters of that equation can be obtained residually (Barten, 1969).

Previous literature shows that the coefficients and elasticities derived from the four different demand systems may differ substantially, highlighting the importance of making an appropriate choice of demand system specification. Comparisons between alternative specifications can be and have been done using goodness-of-fit criteria. Such comparisons have been termed "naive" in that the statistical interpretation is not clear (Malaga and Williams, 2000). An alternative approach developed by Barten (1969) allows for a more appropriate method of demand system selection. The Barten technique artificially nests the four versions of differential demand systems considered here (Rotterdam, AIDS, NBR, and CBS) into a more general model using the Variable Addition Method of McAleer (1983). The method was extended to a combination of vector value functions and applied to a comparison of the demand systems. Given the nature of the dependent variables, the test basically reduces to assessing the extra explanatory power of the vectors of exogenous variables. The Likelihood Ratio Test statistic can be used for this purpose (Barten 1969).

Estimating the Working Models and Calculating their Elasticities

The Rotterdam Model

$$w_i d \ln q_i = \theta_i d \ln Q + \sum_j \pi_{ij} d \ln p_j \tag{77}$$

where i refers to the commodities, potatoes, tomatoes, and onions, j refers to the exporting countries, including India, Egypt, Turkey, and the rest of the world (ROW) for onions, Syria, Jordan, Egypt, Turkey, and ROW for tomatoes, and Syria, Lebanon, Egypt, Turkey, and ROW for potatoes. q_i, p_i refers to the quantities and prices of the ith commodity. w_i refers to the average budget share of the ith commodity.

$$d \ln Q = \sum_j w_i d \ln q_i \ .$$

θ_i, π_{ij} are the parameters importing marginal budget share and Slutsky coefficient, respectively.

Calculating the Elasticities of the Rotterdam model

Expenditure elasticity $\eta_i = \theta_i / w_i$

Slutsky (compensated) elasticities:

Own-price elasticity: $\xi_{ii} = \pi_{ii} / w_i$

Cross-price elasticity: $\xi_{ij} = \pi_{ij} / w_i$ where $i \neq j$

Cournot (uncompensated) elasticities:

Own-price elasticity: $\varepsilon_{ii} = \pi_{ii} / w_i - \theta_i$

Cross-price elasticity: $\varepsilon_{ij} = (\pi_{ij} - \theta_i w_j) / w_i$ where $i \neq j$

The CBS Model

$$w_i (d \ln q_i - d \ln Q) = \beta_i d \ln Q + \sum_j \pi_{ij} d \ln p_j \tag{78}$$

Calculating the Elasticities of the CBS model

Expenditure elasticity: $\eta_i = 1 + \beta_i / w_i$

Slutsky:

Own-price elasticity: $\xi_{ii} = \pi_{ii} / w_i$

Cross-price elasticity: $\xi_{ij} = \pi_{ij} / w_i$ where $i \neq j$

Cournot:

Own-price elasticity: $\varepsilon_{ii} = \pi_{ii} / w_i - (w_i + \beta_i)$

Cross-price elasticity: $\varepsilon_{ij} = (\pi_{ij} - \beta_i w_j)/w_i - w_j$ where $i \neq j$

The AIDS Model

$$dw_i = \beta_i d \ln Q + \sum_j^n \gamma_{ij} d \ln p_j \tag{79}$$

where $dw_i = w_i(d \ln p_i + d \ln q_i - d \ln P - d \ln Q)$, $\quad d \ln P = \sum_j w_i d \ln p_j$

Calculating the Elasticities of the AIDS model

Expenditure elasticity: $\eta_i = 1 + \beta_i / w_i$

Slutsky:

Own-price elasticity: $\xi_{ii} = -1 + \pi_{ii} / w_i + w_i$

Cross-price elasticity: $\xi_{ij} = \pi_{ij} / w_i + w_j$ where $i \neq j$

Cournot:

Own-price elasticity: $\varepsilon_{ii} = -1 + \pi_{ii} / w_i - \beta_i = \pi_{ii} / w_i - (1 + \beta_i)$

Cross-price elasticity: $\varepsilon_{ij} = \pi_{ij} / w_i - \beta_i w_j / w_i = (\pi_{ij} - \beta_i w_j) / w_i$

where $i \neq j$

The NBR Model

$$dw_i + w_i d \ln Q = \theta_i d \ln Q + \sum_j \pi_{ij} d \ln p_j \tag{80}$$

Calculating the Elasticities of the NBR model

Expenditure elasticity: $\eta_i = \theta_i / w_i$

Slutsky: Own-price elasticity: $\xi_{ii} = -1 + \pi_{ii} / w_i + w_i$

Cross-price elasticity: $\xi_{ij} = \pi_{ij} / w_i + w_j$ where $i \neq j$

Cournot: Own-price elasticity: $\varepsilon_{ii} = -1 + \pi_{ii} / w_i - \theta_i = \pi_{ii} / w_i - (1 + \theta_i)$

Cross-price elasticity: $\varepsilon_{ij} = \pi_{ij} / w_i - \theta_i w_j / w_i = (\pi_{ij} - \theta_i w_j) / w_i$

where $i \neq j$

The General Model

$$w_i d \ln q_i = \theta_i d \ln Q + \eta_1 w_i d \ln Q + \sum_j c_{ij} d \ln p_j - \eta_2 \sum_j w_i \left(\delta_{ij} - w_j\right) \, d \ln p_j + \varepsilon_i \quad (81)$$

Calculating the Elasticities of the General model

Expenditure elasticity: $\pi_i = \theta_i / w_i + \eta_1$

Slutsky: $\xi_{ij} = \theta_{ij} / w_i + \eta_2 (\delta_{ij} - w / w_j)$,

$$where \begin{cases} i = j \Rightarrow Own-price \quad elasticity \\ i \neq j \Rightarrow Cross-price \quad elasticity \end{cases}$$

Cournot: $\varepsilon_{ij} = (\delta_{ij} - w_j \theta_i) / w_i + \eta_2 \delta_{ij} - w_j (\eta_1 + \eta_2)$,

$$where \begin{cases} i = j \Rightarrow Own-price \quad elasticity \\ i \neq j \Rightarrow Cross-price \quad elasticity \end{cases}$$

In general we can calculate the Slutsky elasticity from the Cournot elasticity, and vice-versa.

Own-price elasticity: $\varepsilon_{ii} = \xi_{ii} - \eta_i w_i$

Cross-price elasticity: $\varepsilon_{ij} = \xi_{ij} - \eta_i w_j$

Own-price elasticity has three possibilities: greater than one (in absolute value) refers to elastic goods. This means that if price changes by a certain percentage, quantity demanded changes by an even greater percentage. An elasticity less than one in absolute value is inelastic, which means that the percentage change in quantity is less than the percentage change in price. An elasticity equal one is unitary elastic. Cross-price elasticity has two possibilities: a positive sign indicates that two goods are substitutes, while a negative sign indicates that they are complements.

Misspecification Tests

Each estimated model is tested for several misspecification, these tests identify problems in the model such as non-normality, serial correlation (autocorrelation), and heteroskedasticity and functional form. Misspecification arises from the violation of the assumptions underlying the linear regression model. The consequences are biased and inconsistent estimators; which lead to inappropriate inferences and policy recommendations.

Since the demand systems consist of more than one model run simultaneously, the tests are conducted in joint form. This is a comprehensive set of individual tests to check for parameter stability, appropriateness of functional form and independence (Greene, 2000). The following tests are conducted:

1). *Normality*: Tests of normality are statistical inference procedures designed to test that the underlying distribution of a random variable is normally distributed. Two tests are used: Shapiro-Wilks W and Kolmogorov-Smirnov. Shapiro-Wilks's W test is a formal test of normality offered in the SAS UNIVARIATE procedure and is a standard test for normality. The Kolmogorov-Smirnov (K-S) goodness of fit test is used to decide if a sample comes from a population with normal distribution.

2). *Autocorrelation*: Autocorrelation can arise for several reasons, such as inertia, sluggishness of time series, or using an incorrect functional form. In a system of equations, a regular Durbin-Watson statistic cannot be used to test for serial correlation of the system, but we can use it for each equation separately to identify first order autocorrelation. In addition, we can use ARIMA procedure in SAS to identify higher orders of autocorrelation in the residuals.

3). *Independence*: There are two tests performed to check for correctness of the functional form: joint conditional mean and joint conditional variance. The joint conditional mean test simultaneously checks for parameter stability, functional form, and independence. The test is based on an artificial regression on the error term and time trend for parameter stability, functional form and temporal independence. The joint conditional variance test is used to check for dynamic and static heteroskedasticity as well as for stability of σ^2.

Tests for Consistency with Economic Theory

4). *Homogeneity* and *Symmetry* restrictions: In a demand system, homogeneity is the required condition that the sum of all price parameters in a single equation is equal to zero ($\Sigma\ \pi_{ij=0}$). The symmetry restriction specifies $\pi_{ij} = \pi_{ji.}$ The *stest* statement in SAS is used to test homogeneity and symmetry jointly. The SAS output gives the results of a Wald F-test including the p-value. The conditions are assumed to hold if the test fails to reject homogeneity and symmetry conditions.

Data

Quarterly data for 1988.1 through 2003.2 are used for this study. Saudi Arabia imported vegetables from six countries during this time period: Turkey, Syria, Egypt, India, Jordan, and Lebanon. Values of tomatoes and onions imported to and exported from Saudi Arabia are summarized in Table 3. Quantities are summarized in Figure 10. The sample statistics of expenditure shares for each good from each source are summarized in Table 4 and Figures 11-13, measured in Saudi currency (3.75 Saudi Riyals equals one US dollar). The source of domestic product statistics was the Ministry of Agriculture in Saudi Arabia (various issues 1980-2000). The source of imported product statistics was the Ministry of Economics & Planning, Center of Statistics, in Saudi Arabia (1980-2003) and FAO.

Table 4 indicates that the share of consumption of onions accounted for by imports was 66%. Among the six sources of imported onions, Turkey was the largest, accounting for 27% of consumption. Imports from India accounted for 18% of consumption, and imports from Egypt accounted for 9%.

The share of total consumption of tomatoes accounted for by imports was only 13%. Among the six sources of imported tomatoes, Turkey was the largest, followed by Syria and Lebanon (Table 4).

Descriptive statistics for values, quantities, prices, and expenditure shares of tomatoes and onions are reported in Tables 5-12. In some calendar quarters Saudi Arabia did not import vegetables from a particular country because production in that country was out-of-season, or because Saudi Arabia had sufficient domestic production that imports from that country were not desired. In such cases a zero value is used for quantity imported, and price is interpolated from prices of imports from that country in the quarters immediately before and immediately after the zero observation.

Table 5. Descriptive Statistics of Value of Tomatoes Imported by Saudi Arabia from all Sources 1988.1-2003.2 (Saudi Riyals).

Country	Mean	Std.Dev.	Minimum	Maximum	NumCases
Syria	27,315,100	32,663,000	0	127,258,000	62
Jordan	3,276,910	7,303,330	0	39,506,200	62
Egypt	2,608,070	4,248,920	0	18,329,600	62
Turkey	7,529,340	8,702,650	0	31,758,700	62
ROW	2,095,180	2,486,780	0	13,667,700	62
Total	42,824,600	36,162,400	249,379	155,483,000	62

Sources: Calculated from the data of Ministry of Economics & Planning, Central Department of Statistics, Saudi Arabia, 2003.

Table 6. Descriptive Statistics of Quantity of Tomatoes Imported by Saudi Arabia from all Sources 1988.1-2003.2 (Kg).

Country	Mean	Std.Dev.	Minimum	Maximum	NumCases
Syria	15,050,100	17,114,200	0	68,096,000	62
Jordan	5,501,520	12,194,600	0	65,888,300	62
Egypt	2,774,400	4,289,020	0	16,842,200	62
Turkey	11,376,400	13,433,000	0	52,628,500	62
ROW	2,676,780	3,528,960	0	17,313,900	62
Total	37,379,200	27,241,000	161,740	98,299,700	62

Sources: Calculated from the data of Ministry of Economics & Planning, Central Department of Statistics, Saudi Arabia, 2003.

Table 7. Descriptive Statistics of Price of Tomatoes Imported by Saudi Arabia from all Sources 1988.1-2003.2 (S.R./Kg).

Country	Mean	Std.Dev.	Minimum	Maximum	NumCases
Syria	1.76174	0.93432	0.16248	5.98723	62
Jordan	0.73603	0.35506	0.26067	1.85269	62
Egypt	0.93101	0.32081	0.47770	2.35116	62
Turkey	0.74688	0.33424	0.41225	2.88671	62
ROW	1.02469	0.45101	0.59814	2.50897	62
Total	1.20411	0.48797	0.60029	2.84312	62

Sources: Calculated from the data of Ministry of Economics & Planning, Central Department of Statistics, Saudi Arabia, 2003.

Table 8. Descriptive Statistics of Average Expenditure Shares of Tomatoes Imported By Saudi Arabia from all Sources 1988.1-2003.2 (%).

Country	Mean	Std.Dev.	Minimum	Maximum	NumCases
Syria	0.472864	0.332557	0.00186737	0.93796	61
Jordan	0.145172	0.275013	0	0.978356	61
Egypt	0.128416	0.173854	0	0.576168	61
Turkey	0.173163	0.129766	0	0.543581	61
ROW	0.0803845	0.0866916	0.00793799	0.375833	61

Sources: Calculated from the data of Ministry of Economics & Planning, Central Department of Statistics, Saudi Arabia, 2003.

Table 9. Descriptive Statistics of Value of Onions Imported by Saudi Arabia from all Sources 1988.1-2003.2 (Saudi Riyals).

Country	Mean	Std.Dev.	Minimum	Maximum	NumCases
India	5,106,580	4,995,580	422	21,793,300	62
Egypt	8,125,700	5,737,460	135,644	33,338,100	62
Turkey	11,028,300	7,397,760	316,700	29,287,300	62
ROW	2,900,540	2,979,250	123,354	14,174,700	62
Total	27,161,100	9,026,090	6,815,540	49,098,400	62

Sources: Calculated from the data of Ministry of Economics & Planning, Central Department of Statistics, Saudi Arabia, 2003.

Table 10. Descriptive Statistics of Quantity of Onions Imported by Saudi Arabia from all Sources 1988.1-2003.2 (Kg).

Country	Mean	Std.Dev.	Minimum	Maximum	NumCases
India	7,637,760	7,471,730	351	31,235,100	62
Egypt	13,628,500	9,851,640	165,480	53,088,200	62
Turkey	17,011,300	11,259,200	461,681	45,731,900	62
ROW	3,126,910	3,255,640	125,000	13,374,600	62
Total	41,404,500	12,998,200	9,798,060	69,452,100	62

Sources: Calculated from the data of Ministry of Economics & Planning, Central Department of Statistics, Saudi Arabia, 2003.

Table 11. Descriptive Statistics of Price of Onions Imported by Saudi Arabia from all Sources 1988.1-2003.2 (S.R./Kg).

Country	Mean	Std.Dev.	Minimum	Maximum	NumCases
India	0.75241	0.24626	0.38675	1.61344	62
Egypt	0.65388	0.15370	0.43264	1.03846	62
Turkey	0.65128	0.09156	0.30656	0.79742	62
ROW	0.99416	0.25056	0.59551	1.71494	62
Total	0.65489	0.05840	0.51392	0.75862	62

Sources: Calculated from the data of Ministry of Economics & Planning, Central Department of Statistics, Saudi Arabia, 2003.

Table 12. Descriptive Statistics of Average Expenditure Shares of Onions Imported by Saudi Arabia from all Sources 1988.1-2003.2 (%).

Country	Mean	Std.Dev.	Minimum	Maximum	NumCases
India	0.17908	0.12349	0.00185	0.54815	61
Egypt	0.30880	0.16819	0.01604	0.75187	61
Turkey	0.40290	0.17296	0.04177	0.76691	61
ROW	0.10921	0.09168	0.01860	0.42190	61

Sources: Calculated from the data of Ministry of Economics & Planning, Central Department of Statistics, Saudi Arabia, 2003.

CHAPTER V

RESULTS AND DISCUSSION

Tests of Symmetry and Homogeneity Restrictions

For both vegetables, five restricted demand systems were estimated including the restricted general demand system using the SAS (Statistical Analysis System) seemingly unrelated regression (SUR) option. The models were estimated imposing homogeneity and symmetry conditions. The symmetry condition was imposed by restricting $\pi_{ij} = \pi_{ji}$ on the Rotterdam and CBS models, and $\gamma_{ij} = \gamma_{ji}$ on the AIDS and NBR models. The null hypothesis in each specific model and the general model is that homogeneity and symmetry hold. In order to consider the restriction valid we must fail to reject the null hypothesis.

The first set of restricted demand system estimated was for tomatoes imported to Saudi Arabia from Syria, Jordan, Egypt, Turkey, and the rest of the world (ROW). The second was for imported onions from India, Egypt, Turkey and ROW.

When estimating a restricted system of equations one equation of the system must be dropped in order to avoid singularity. Singularity is due to the adding up condition. If the model is singular, the covariance matrix of the residuals (Σ) is singular and its inverse does not exist. Barten (1969) demonstrated that dropping one equation and estimating (n-

1) system avoids singularity, yet provides estimates that are invariant to which equation is dropped (Judge et. al., 1988).

The five systems were also estimated as unrestricted models, using SAS without the SUR option. In this case, the homogeneity and symmetry conditions were not imposed but both restrictions were tested. The homogeneity condition tested $\Sigma_j \pi_{ij} = 0$, for the Rotterdam and CBS demand systems, while for the NBR and AIDS models it tested $\Sigma_j \gamma_{ij} = 0$. The symmetry condition tested was $\pi_{ij} = \pi_{ji}$ for the Rotterdam and CBS models, and $\gamma_{ij} = \gamma_{ji}$ for the AIDS and NBR models, and $c_{ij} = c_{ji}$, $i \neq j$.

Table 13 indicates that for tomatoes, the only model for which both homogeneity and symmetry hold is the Rotterdam model. The p-value for homogeneity is 0.8341, indicating that there is an 83% probability of being correct in failing to reject the null hypothesis of homogeneity. Although the null hypothesis of symmetry by itself is rejected at the 7% level of significance, the full set of restrictions, homogeneity together with symmetry, is not rejected. For non-Rotterdam models, these restrictions are rejected at typical levels of significance, with the possible exception being the NBR model, for which the joint restrictions are rejected at the 12% level of significance and homogeneity is not rejected. Table 13 also shows that, for onions, the restrictions are not rejected for any of the models.

Autocorrelation was tested using the Durbin-Watson (DW) test to see if first-order autocorrelation was present in the residuals of the individual equation regression analysis. As a rule of thumb, a DW statistic around 2 implies that no first-order

Table 13. Tests of Homogeneity and Symmetry Conditions on Demand Systems.

Model	Testing on	Tomatoes P-values	Onions P-values
Rotterdam	Homogeneity	0.8341	0.1439
	Symmetry	0.0667*	0.2323
	Homogeneity + Symmetry	0.2128	0.3935
AIDS	Homogeneity	0.0140*	0.1863
	Symmetry	0.0001*	0.3300
	Homogeneity + Symmetry	0.0001*	0.5240
NBR	Homogeneity	0.7372	0.0917*
	Symmetry	0.0310*	0.2023
	Homogeneity + Symmetry	0.1159	0.3313
CBS	Homogeneity	0.0179*	0.2766
	Symmetry	0.0001*	0.3627
	Homogeneity + Symmetry	0.0001*	0.5887
General Model	Homogeneity	0.0602*	0.4619
	Symmetry	0.0011*	0.4552
	Homogeneity + Symmetry	0.0031*	0.2826

* indicates rejection at the $\alpha = 0.10$ level of significance.

autocorrelation is present. The result indicated that DW statistics for the five demand systems ranged from 1.8 to 2.8, which, in this case, showed that there was no evidence of first order autocorrelation. A test for higher order autocorrelation in the residuals used ARIMA, and found that there was not a significant problem from AR(1) to AR(4).

The other tests performed were joint conditional mean and joint conditional variance tests. The joint conditional mean test simultaneously checks for the appropriateness of functional form, independence and the stability of the parameters (McGuirk et.al, 1995). The joint conditional variance test simultaneously checks for static and dynamic heteroskedasticity as well as stability of the variance-covariance matrix.

Normality of the error term in the demand systems was also tested for each model for both the restricted and unrestricted versions (Tables 14 and 15). Two statistics were used to test the normality of the error term: Shapiro-Wilks and Komogorov-Smirnov in SAS. For the restricted models (Table 14) for tomatoes, the tests rejected normality for Jordan and Turkey for all models, as well as Egypt for the NBR model. For onions, the tests failed to reject normality for all countries for all models for at least one of the tests.

For the unrestricted models (Table 15) for tomatoes, the tests rejected normality for all models except the general model for all countries but Syria. Normality was not rejected for any of the countries with the general model. For onions, normality was rejected only for ROW.

Table 14. Normality Test of Residuals of Restricted Demand Models for each Commodity

		Rotterdam		AIDS		NBR		CBS		General Model	
Model	Countries	Shapiro Wilks	Kosmogorov Smirnov	Shapiro Wilks	Kosmogorov Smirnov	Shapiro Wilks	Kosmogorov Smirnov	Shapiro Wilks	Kosmogorov Smirnov	Shapiro Wilks	Kosmogorov Smirnov
Tests		P-Value	P-Value	P-Value	P-Value	P-Value	P-Value	P-Value	P-Value	P-Value	P-Value
Tomatoes	Syria	0.2259	0.1500	0.1972	0.1500	0.1031	0.1500	0.2259	0.1500	0.9477	0.1428
	Jordan	<0.0001	0.0100	<0.0001	0.0100	0.0100	0.0100	0.0001	0.0100	0.8142	0.1867
	Egypt	0.3429	0.1500	0.3094	0.1500	0.0011	0.0964	0.3429	0.1500	0.9297	0.0979
	Turkey	<0.0001	0.0100	<0.0001	0.0100	<0.0001	0.0100	0.0001	0.0100	0.8355	0.1541
Onions	India	0.6223	0.1500	0.7453	0.1500	0.1850	0.1500	0.6223	0.1500	0.9880	0.0901
	Egypt	0.8614	0.1500	0.7202	0.1500	0.6781	0.1500	0.8614	0.1500	0.9927	0.0776
	Turkey	0.2125	0.1500	0.2407	0.1500	0.1524	0.1500	0.2125	0.1500	0.9776	0.0922

Shadowing indicates that normality is rejected at the 10% significance level.

Table 15. Normality Test of Residuals of Unrestricted Demand Models for each Commodity

		Rotterdam		AIDS		NBR		CBS		General Model	
Comm.	Country	Shapiro Wilks P-Value	Kolmogorov Smirnov P-Value	Shapiro Wilks P-Value	Kolmogorov Smirnov P-Value	Shapiro Wilks P-Value	Kolmogorov Smirnov P-Value	Shapiro Wilks P-Value	Kolmogorov Smirnov P-Value	Shapiro Wilks P-Value	Kolmogorov Smirnov P-Value
Tomatoes	Syria	0.1519	0.1500	0.1972	0.1500	0.1031	0.1500	0.2259	0.1500	0.9637	0.0985
	Jordan	0.8092	0.1923	0.0001	0.0100	0.0001	0.0100	0.0001	0.0100	0.8192	0.1787
	Egypt	0.0013	0.0874	0.3094	0.1500	0.0011	0.0964	0.3429	0.1500	0.9170	0.1062
	Turkey	0.0001	0.0100	0.0001	0.0100	0.0001	0.0100	0.0001	0.0100	0.8681	0.1603
	ROW	0.0001	0.0100	0.0001	0.0104	0.0002	0.0134	0.0001	0.0100	0.9162	0.1484
Onions	India	0.1042	0.1466	0.7453	0.1500	0.1850	0.1500	0.6223	0.1500	0.4473	0.0489
	Egypt	0.8535	0.1500	0.7202	0.1500	0.6781	0.1500	0.8614	0.1500	0.9806	0.1500
	Turkey	0.1367	0.1500	0.2407	0.1500	0.1524	0.1500	0.2125	0.1500	0.3876	0.1500
	ROW	0.0272	0.0794	0.0080	0.0100	0.0426	0.0495	0.0031	0.0100	0.0093	0.0100

Shadowing indicates that normality is rejected at the 10% significance level.

Parameter Estimates - General Model

Barten (1993) suggested a general model that nests all four models (Rotterdam, AIDS, NBR, CBS). There are two additional parameters ($\delta 1$ and $\delta 2$) to be estimated. If both equal 0, then the general model is a Rotterdam model, if $\delta 1 = 1$ and $\delta 2 = 0$, the general model is a CBS model, if $\delta 1 = 0$ and $\delta 2 = -1$, the general model is an NBR model; and if $\delta 1 = 1$ and $\delta 2 = -1$, it is an AIDS model. Nested tests of the restricted general models for tomatoes and onions shown in Table 16 indicate that joint F-tests of these restrictions rejected each of the four specific models for both tomatoes and onions.

A test for autocorrelation of degree one (lag 1) up to degree 4 (lag 4) of the residual of the general demand system for onions and tomatoes was done using the "*identify*" statement in PROC ARIMA in SAS. The test failed to reject autocorrelation.

Results for all the models are presented in this chapter. However, since all four specific models are rejected for both tomatoes and onions, since normality is not rejected for tomatoes or for onions for the general models, and since homogeneity and symmetry restrictions are rejected for tomatoes but are not rejected for onions with the general model, conclusions presented later focus on the unrestricted general model for tomatoes and the restricted general model for onions.

Restricted General Model for Imported Tomatoes

Table 17 indicates for the restricted general model for tomatoes that all own-price parameters were negative, although the only ones significant at the $\alpha = 0.10$ level were for Syria and Turkey. Cross-price parameters were positive except

Table 16. Nested Tests of Parameter Restrictions on General Model

	Restricted Model						Unrestricted Model					
	Tomatoes			Onions			Tomatoes			Onions		
Models	n1	n2	P-value	n1	n2	P-value	n1	n2	P-value	n1	n2	P-value
Rotterdam	0	0	0.0001	0	0	0.0001	0	0	0.0001	0	0	0.0001
AIDS	1	-1	0.0001	1	0	0.0016	1	-1	0.0001	1	0	0.0072
AIDS	1	1	0.0001	0	-1	0.0001	1	1	0.0001	0	-1	0.0001
NBR	1	0	0.0001	0	1	0.0001	1	0	0.0001	0	1	0.0001
CBS	0	1	0.0001	1	-1	0.0067	0	1	0.0001	1	-1	0.0238
CBS	0	-1	0.0001	1	1	0.0067	0	-1	0.0001	1	1	0.0010

Table 17. Coefficients of Restricted General Demand Model For Imported Tomatoes.

Country	Intercept	dlnQ	WidlnQ $\delta 1$	Syria dlnp1	Jordan dlnp2	Egypt dlnp3	Turkey dlnp4	ROW dlnp5	wi*(dlnpi-dlnP) $\delta 2$	P value
Syria	0.0403	0.4788	0.4916	-0.4301	-0.0082	-0.0161	0.4002	0.0542	0.54821	
P-Value	0.0901	<.0001	<.0001	0.0038	0.9253	0.8640	0.0002	0.6294	0.0095	<.0001
Jordan	0.0050	0.0016	0.3114	-0.0082	-0.0022	-0.0183	0.0765	-0.0478	-0.1394	
P-Value	0.8248	0.9458	0.0010	0.9253	0.9856	0.8588	0.4173	0.6208	0.9390	0.1236
Egypt	-0.0253	0.0048	0.3375	-0.0161	-0.0183	-0.0949	-0.0392	0.1684	1.0154	
P-Value	0.3165	0.8628	<.0001	0.8640	0.8588	0.5302	0.7196	0.0767	0.3675	0.0049
Turkey	-0.0204	0.0350	0.7527	0.4002	0.0765	-0.0392	-0.4608	0.0234	1.0152	
P-Value	0.3789	0.4276	0.0005	0.0002	0.4173	0.7196	0.0214	0.8556	0.4294	<.0001
ROW	-0.0044	0.0002	0.3027	0.0542	-0.0478	0.1684	0.0234	-0.0361	-0.7523	
P-Value	0.4949	0.9871	<.0001	0.6294	0.6208	0.0767	0.8556	0.5914	0.1970	<.0001

for Syria and Jordan, Syria and Egypt, Jordan and Egypt, Egypt and Turkey, and ROW and Jordan. These negative cross-price elasticities indicated complementary relationships. There was no autocorrelation detected.

Parameter Estimates for Specific Models for Tomatoes

For tomatoes, results of the Rotterdam model with the homogeneity and symmetry conditions imposed are reported in Table 18. All own-price parameter estimates were negative, although only the ones for Syria and Turkey were significant. The cross-price parameter estimates were negative for Turkey and Jordan, Turkey and Egypt, ROW and Syria, and ROW and Jordan, indicating complementarity. The other cross-price elasticities were positive, indicating that tomatoes for those countries are Hicksian substitutes. Results of the AIDS model with the homogeneity and symmetry conditions imposed are reported in Table 19. Since tests rejected those restrictions, the results are not discussed.

The coefficients for the restricted NBR model are reported in Table 20. All own-price parameters for the demand system had negative signs with the exception of ROW. Parameters were significant for only Syria and Turkey. Cross-price parameters were negative for Turkey and Jordan, Turkey and Egypt, Turkey and ROW, Syria and ROW, and Jordan and ROW. The others were positive. Results of the CBS model with the homogeneity and symmetry conditions imposed are reported in Table 21, although, as with the AIDS model, tests rejected those restrictions.

Table 18. Coefficients of Restricted Rotterdam Demand Model for Imported Tomatoes

Countries	Intercept	dlnQ	Syria dlnp1	Jordan dlnp2	Egypt dlnp3	Turkey dlnp4	ROW dlnp5	Model F test	DW test
Syria	0.1450	0.6748	-0.5548	0.0883	0.0501	0.4498	-0.0334		
P-Value	0.0442	<.0001	0.0003	0.3475	0.6124	0.0002	0.4864	<.0001	2.23
Jordan	0.0128	0.0093	0.0883	-0.0232	0.0129	-0.0571	-0.0908		
P-Value	0.8149	0.6968	0.3475	0.8347	0.8416	0.5604	0.3876	0.7849	2.01
Egypt	-0.0976	0.0639	0.0501	0.0129	-0.0955	-0.0567	0.0892		
P-Value	0.1042	0.0090	0.6124	0.8416	0.4750	0.6079	0.1150	0.0121	2.1
Turkey	-0.0469	0.1814	0.4498	-0.0571	-0.0567	-0.3943	0.0585		
P-Value	0.4438	<.0001	0.0002	0.5604	0.6079	0.0122	0.5988	<.0001	2.09
ROW	-0.0132	0.0675	-0.0334	-0.0908	0.0892	0.0585	-0.0489		
P-Value	0.5743	<.0001	0.4864	0.3876	0.1150	0.5988	0.4556	<.0001	2.42

Table 19. Coefficients of Restricted AIDS Demand Model for Imported Tomatoes

Countries	Intercept	dlnQ	Syria dlnp1	Jordan dlnp2	Egypt dlnp3	Turkey dlnp4	ROW dlnp5	Model F test	DW test
Syria	0.0348	0.3070	0.2092	-0.2877	-0.1759	0.1939	0.0605		
P-Value	0.6143	<.0001	0.1423	0.0041	0.1514	0.0513	0.4327	<.0001	2.8
Jordan	0.0098	-0.0280	-0.2877	0.0342	0.0665	0.1464	0.4054		
P-Value	0.8721	0.2822	0.0041	0.7909	0.5824	0.1153	0.5969	0.0014	1.78
Egypt	0.0131	-0.1259	-0.1759	0.0665	-0.0249	0.0280	0.1063		
P-Value	0.8650	0.0002	0.1514	0.5824	0.8949	0.7977	0.2398	0.0001	2.2
Turkey	-0.0527	-0.0187	0.1939	0.1464	0.0280	-0.2103	-0.1580		
P-Value	0.3167	0.4171	0.0513	0.1153	0.7977	0.0831	0.0483	0.0754	2.1
ROW	-0.0052	-0.1292	0.0605	0.0405	0.1063	-0.1580	-0.0033		
P-Value	0.8955	<.0001	0.4327	0.5969	0.2398	0.0483	0.9768	<.0001	2.8

Table 20. Coefficients of Restricted NBR Demand Model for Imported Tomatoes

Countries	Intercept	dlnQ	Syria dlnp1	Jordan dlnp2	Egypt dlnp3	Turkey dlnp4	ROW dlnp5	Model F test	DW Test
Syria	0.1443	0.6799	-0.4722	0.0589	0.0331	0.4265	-0.0463		
P-Value	0.0535	<.0001	0.0030	0.5396	0.7500	0.0007	0.2829	<.0001	2.2
Jordan	0.0159	0.0161	0.0589	-0.0311	0.0031	-0.0190	-0.0120		
P-Value	0.7708	0.4622	0.5396	0.7887	0.9756	0.8401	0.8009	0.7486	2
Egypt	-0.0991	0.0652	0.0331	0.0031	-0.0425	-0.0724	0.0787		
P-Value	0.0958	0.0073	0.7500	0.9756	0.7764	0.5238	0.1309	0.0088	2.1
Turkey	-0.0498	0.1732	0.4265	-0.0190	-0.0724	-0.2773	-0.0579		
P-Value	0.4202	<.0001	0.0007	0.8401	0.5238	0.0689	0.2824	<.0001	2.1
ROW	-0.0111	0.0622	-0.0463	-0.0120	0.0787	-0.0579	0.0148		
P-Value	0.5939	<.0001	0.2829	0.8009	0.1309	0.2824	0.7985	<.0001	2.3

Table 21. Coefficients of Restricted CBS Demand Model for Imported Tomatoes

Countries	Intercept	dlnQ	Syria dlnp1	Jordan dlnp2	Egypt dlnp3	Turkey dlnp4	ROW dlnp5	Model F test	DW test
Syria	0.0354	0.3033	0.1150	-0.2713	-0.1444	0.2173	0.0834		
P-Value	0.5939	<.0001	0.3974	0.0057	0.2320	0.0270	0.2435	<.0001	2.7
Jordan	0.0075	-0.0288	-0.2713	0.0306	0.0633	0.1529	0.0245		
P-Value	0.9024	0.2667	0.0057	0.8135	0.6021	0.1030	0.7362	0.0021	1.7
Egypt	0.0140	-0.1293	-0.1444	0.0633	-0.0613	0.0502	0.0922		
P-Value	0.8562	0.0001	0.2320	0.6021	0.7461	0.6504	0.2784	0.0001	2.1
Turkey	-0.0500	-0.0175	0.2173	0.1529	0.0502	-0.3191	-0.1013		
P-Value	0.3397	0.4451	0.0270	0.1030	0.6504	0.0107	0.1821	0.0312	2.1
ROW	-0.0073	-0.1239	0.0834	0.0245	0.0922	-0.1013	-0.0669		
P-Value	0.8412	<.0001	0.2435	0.7362	0.2784	0.1821	0.5130	<.0001	2.8

Elasticities for Tomatoes – Restricted Demand Systems

Conditional import expenditure elasticities, conditional Slutsky price elasticities, and conditional Cournot price elasticities for tomatoes and onions are reported in this section. All elasticities were calculated based on their parameter estimates and using the sample average mean of import expenditure share from 1988.1 to 2003.2.

There were two types of own-price elasticities calculated: Slutsky (compensated) and Cournot (uncompensated). Compensated own-

price elasticities indicate the percentage response to quantities demanded that resulted from a one percent change in price holding real expenditure on imported vegetable constant, while uncompensated price elasticities (conditional Cournot) are the percentage response to quantities demanded resulting from a 1 percent change in price, holding nominal expenditures on imported commodities constant (Schmitz and Seale, 2002).

Both Slutsky and Cournot own-price elasticities were calculated based on parameter estimates from the Rotterdam, AIDS, NBR, CBS, and general demand systems with both homogeneity and symmetry conditions imposed. Along the diagonals of these tables are the numbers corresponding to the change in import quantities caused by a change in the price of the same goods. Own-price import elasticities are important because they indicate whether or not would changes in prices will decrease or increase amount of money spent by importers on those goods.

Expenditure Elasticities

Expenditure elasticities of tomatoes for the restricted Rotterdam, AIDS, NBR, CBS, and general models are shown in Table 22. All expenditure elasticities for imported

Table 22. Own, Cross-Price and Expenditure Elasticities of Restricted Demand Equations for Imported Tomatoes.

		Expenditure	Slutsky Own Price and Cross Price Elasticities Sii and Sij					Cournot Own Price and Cross Price Elasticities Cii and Cij				
Country	Model	Elasticites	Syria	Jordan	Egypt	Turkey	ROW	Syria	Jordan	Egypt	Turkey	ROW
Syria	Rott.	1.4285	-1.1745	0.1870	0.1061	0.9522	-0.0708	-1.8493	-0.4878	-0.5687	0.2774	-0.7456
	AIDS	1.6499	-0.0848	-0.4637	-0.2416	0.5822	0.2079	-0.8642	-1.2431	-1.0210	-0.1971	-0.5715
	NBR	1.4394	-1.5272	0.2699	0.2008	1.0748	-0.0182	-2.2072	-0.4101	-0.4791	0.3948	-0.6982
	CBS	1.6422	0.2435	-0.5744	-0.3057	0.4600	0.1765	-0.5322	-1.3501	-1.0814	-0.3157	-0.5992
	General	0.4967	-0.3622	0.5308	0.5142	1.3954	0.6629	-1.3322	-0.4391	-0.4557	0.4254	-0.3070
Jordan	Rott	0.0639	0.6080	-0.1598	0.0885	-0.3928	-0.6251	0.5987	-0.1691	0.0792	-0.4021	-0.6344
	AIDS	0.8073	-1.5078	-0.6190	0.5882	1.1797	0.3589	-1.6251	-0.7363	0.4709	1.0625	0.2416
	NBR	0.1111	0.8775	-1.0687	0.1522	0.0414	-0.0024	0.8614	-1.0849	0.1361	0.0253	-0.0186
	CBS	0.8016	-1.8677	0.2107	0.4359	1.0527	0.1683	-1.9841	0.0942	0.3195	0.9363	0.0518
	General	0.0035	-0.1960	-0.1546	-0.2651	0.3874	-0.4684	-0.2226	-0.1813	-0.2917	0.3607	-0.4950
Egypt	Rott	0.4893	0.3835	0.0983	-0.7308	-0.4336	0.6826	0.3195	0.0344	-0.7947	-0.4976	0.6187
	AIDS	0.0367	-0.8732	0.6538	-1.0598	0.3861	0.8931	-1.1298	0.3973	-1.3164	0.1295	0.6365
	NBR	0.4991	3.0061	0.1692	-1.1945	-0.3824	0.6820	2.9408	0.1040	-1.2597	-0.4477	0.6168
	CBS	0.0106	-1.1049	0.4846	-0.4692	0.3839	0.7057	-1.1063	0.4832	-0.4706	0.3825	0.7043
	General	0.0103	-0.1075	-0.1244	-0.7107	-0.2849	1.3042	-0.1585	-0.1753	-0.7616	-0.3358	1.2532
Turkey	Rott.	1.0556	2.6177	-0.3321	-0.3298	-2.2947	0.3388	2.4363	-0.5135	-0.5112	-2.4761	0.1574
	AIDS	0.8912	1.6006	0.9974	0.2936	-2.0518	-0.8399	1.4101	0.8068	0.1031	-2.2424	-1.0304
	NBR	1.0080	2.9547	0.0350	-0.2909	-2.4419	-0.2568	2.7814	-0.1382	-0.4641	-2.6151	-0.4301
	CBS	0.8984	1.2647	0.8901	0.2920	-1.8572	-0.5895	1.1103	0.7357	0.1376	-2.0116	-0.7439
	General	0.0379	3.3442	1.4606	0.7869	-1.6666	1.1513	3.0054	1.1218	0.4481	-2.0054	0.8125
ROW	Rott.	0.8456	-0.4188	-1.1377	1.1177	0.7293	-0.2905	-0.4894	-1.2083	1.0471	0.6587	-0.3611
	AIDS	-0.6184	1.2303	0.6532	1.4623	-1.8080	-0.9616	1.2796	0.7025	1.5117	-1.7586	-0.9123
	NBR	0.7786	-0.1078	-0.0044	1.1167	-0.5529	-0.7352	-0.1699	-0.0666	1.0545	-0.6151	-0.7974
	CBS	-0.5517	1.0448	0.3063	1.1554	-1.2691	-0.8382	1.0888	0.3503	1.1995	-1.2250	-0.7942
	General	0.0005	-0.0735	-1.3511	1.3580	-0.4595	-1.2041	-0.0378	-1.3154	1.3937	-0.4238	-1.1684

Shadowing indicates that symmetry and homogeneity restrictions were rejected.

tomatoes from Syria for all models were greater than one. This means that as Saudi Arabian expenditures for imported tomatoes increased by 1%, the share of the expenditures accounted for by imports from Syria increased by more than 1%.

In contrast, expenditure elasticities for imported tomatoes from Jordan are less than one for all models. As Saudi expenditures for imported tomatoes increased by 1%, the share of those expenditures accounted for by imports from Jordan increased by less than 1%.

The magnitudes of expenditure elasticities for Egypt are quite variable across models. For Turkey, the elasticities are near unitary. The ROW elasticities are difficult to explain, since they are both positive and negative, depending on the model.

Own-Price Elasticities for Imported Tomatoes

The own-price elasticities for tomatoes are also reported in Table 22. They are negative for all exporting countries for all models except that under the CBS model for Syria and Jordan the signs are positive. The own-price elasticities are elastic for Turkey and Syria, and inelastic for ROW, Jordan, and Egypt. That means that for Syria, for example, an increase of tomato price by one percent would decrease demand for Syrian tomatoes by 1.17 percent under the Rotterdam, and by 1.52 percent under the NBR model, but only by 0.40 percent under the general model.

Cross-Price Elasticities for Imported Tomatoes

For tomatoes, Table 22 indicates that there was no apparent pattern in Slutsky cross-price elasticities. The elasticity was positive for Turkey and Syria. This means that imports from Turkey and Syria were viewed as substitutes. The results were the same for Cournot cross-price elasticities. Most of the other exporting countries had negative signs under AIDS and CBS models. This means that tomatoes from those country pairs had a complementary relationship for Saudi Arabian importers. That complementary relationship may result from different end uses for tomatoes from the two different sources. For example, tomatoes from one source may be used in salads, while tomatoes from the other source may be used in cooking, with both kinds used more when they are in season.

Elasticities for Tomatoes – Unrestricted Demand Systems

Expenditure Elasticities

Expenditure elasticities of tomatoes for the unrestricted Rotterdam, AIDS, NBR, CBS, and general models are shown in Table 23. All expenditure elasticities for imported tomatoes from Syria for all models except the general model were greater than one. For these models, this means that as Saudi Arabian expenditures for imported tomatoes increased by 1%, the share of the expenditures accounted for by imports from Syria increased by more than 1%. The general model expenditure elasticity was 0.397.

The expenditure elasticities for Jordan were close to zero for all models. For Egypt and Turkey, the magnitudes are near unity, except that the general model has much lower estimates, near 0.25 for Egypt and near 0 for Turkey. As with the restricted model, the ROW elasticities are difficult to explain, since they are both positive and negative, depending on the model.

Table 23. Own, Cross-Price and Expenditure Elasticities of Unrestricted Demand Equations for Imported Tomatoes

		Expenditure	Slutsky Own Price and Cross Price Elasticities Sii and Sij					Cournot Own Price and Cross Price Elasticities Cii and Cij				
Country	Models	Elasticities	Syria	Jordan	Egypt	Turkey	ROW	Syria	Jordan	Egypt	Turkey	ROW
Syria	Rotter.	**1.3418**	**-1.0237**	0.8963	0.1478	1.0556	-0.8081	**-1.6576**	0.2624	-0.4860	0.4218	-1.4419
	AIDS	**1.5160**	**-0.2274**	0.4714	0.2259	0.1114	0.0194	**-0.9435**	-0.2447	-0.4902	-0.6047	-0.6968
	NBR	**1.3478**	**0.3253**	1.0676	0.2743	1.2119	-0.8090	**-0.3114**	0.4309	-0.3624	0.5752	-1.4457
	CBS	**1.5100**	**0.1294**	0.3001	0.1479	-0.0449	-0.7261	**-0.5839**	-0.4132	-0.5654	-0.7582	-1.4394
	General	**0.3970**	**-1.4709**	0.2758	-0.0095	0.3841	-0.4822	**-2.0597**	-0.3131	-0.5984	-0.2047	-1.0711
Jordan	Rotter.	**-0.1035**	0.0647	**-0.7148**	0.1555	-0.5572	-1.7993	0.0797	**-0.6997**	0.1705	-0.5422	-1.7843
	AIDS	**0.2691**	-2.9329	**-1.3288**	-0.2816	0.7510	0.6590	-2.9720	**-1.3679**	-0.3206	0.7119	0.6199
	NBR	**-0.1300**	0.4771	**-1.4908**	0.2635	-0.4042	-1.8835	0.4960	**-1.4719**	0.2824	-0.3854	-1.8646
	CBS	**0.2957**	-3.3449	**0.3957**	-0.3897	0.5983	-3.7258	-3.3878	**0.3527**	-0.4326	0.5553	-3.7687
	General	**0.1136**	-4.1512	**-2.9199**	-2.9283	-3.0217	-5.7763	-3.8500	**-2.6187**	-2.6271	-2.7205	-5.4751
Egypt	Rotter.	**0.9018**	0.2116	-1.8706	**-1.0558**	-0.8179	4.2398	0.0938	-1.9885	**-1.1737**	-0.9358	4.1220
	AIDS	**0.7829**	-0.9284	-1.4248	**-0.3671**	1.6436	1.5516	-1.0308	-1.5271	**-0.4694**	1.5413	1.4493
	NBR	**0.9150**	0.4988	-1.8254	**-1.6914**	-0.9652	4.3729	0.3792	-1.9449	**-1.8110**	-1.0848	4.2533
	CBS	**0.7698**	1.2157	-1.4700	**0.2685**	1.7909	6.3072	1.1151	-1.5706	**0.1679**	1.6903	6.2066
	General	**0.2468**	-3.0274	-4.4843	**-2.6390**	-3.4685	2.3831	-2.8242	-4.2811	**-2.4358**	-3.2653	2.5863
Turkey	Rotter.	**1.1516**	2.6378	-0.4221	0.1413	**-1.7460**	0.8519	2.4399	-0.6200	-0.0566	**-1.9438**	0.6540
	AIDS	**1.1911**	2.6757	0.5570	4.1838	**-0.8167**	0.0913	2.4710	0.3524	3.9791	**-1.0214**	-0.1134
	NBR	**1.1841**	2.9338	-0.3797	0.1684	**-1.8726**	0.9050	2.7303	-0.5832	-0.0351	**-2.0760**	0.7015
	CBS	**1.1609**	2.3795	0.5148	0.5090	**-0.6900**	1.0293	2.1801	0.3153	0.3095	**-0.8895**	0.8298
	General	**0.0062**	3.0887	1.4004	1.2879	**-0.3005**	1.7239	2.7656	1.0772	0.9648	**-0.6236**	1.4008
ROW	Rotter.	**0.8198**	-0.0849	0.0319	0.2667	-0.1345	**-0.7187**	-0.1504	-0.0335	0.2013	-0.2000	**-0.7842**
	AIDS	**-0.7796**	2.1170	-0.9785	-1.3359	-4.0509	**-3.1307**	2.1792	-0.9163	-1.2737	-3.9887	**-3.0685**
	NBR	**0.7413**	0.1697	0.2016	0.3044	-0.8240	**-0.8920**	0.1105	0.1424	0.2452	-0.8832	**-0.9512**
	CBS	**-0.7009**	2.1895	-1.1974	-1.4148	-2.2698	**-1.4648**	2.2455	-1.1415	-1.3588	-2.2139	**-1.4088**
	General	**0.6971**	5.7471	-0.6758	1.2730	-0.2391	**-0.1294**	5.4275	-0.9954	0.9534	-0.5586	**-0.4490**

Own-Price Elasticities for Imported Tomatoes

The own-price elasticities for tomatoes are also reported in Table 23. They are negative for all exporting countries for all models except that under the CBS model for Jordan and Egypt and under the NBR model for Syria the signs are positive. For the general model, the own-price elasticities are elastic for Syria, Jordan, and Egypt, and inelastic for Turkey and ROW. That means that for Syria, for example, an increase of tomato price by one percent would decrease quantity demanded for Syrian tomatoes by 1.47 percent under the general model.

Cross-Price Elasticities for Imported Tomatoes

For tomatoes, Table 23 indicates that there was no apparent pattern in Slutsky cross-price elasticities. The results were similar for Cournot cross-price elasticities. Focusing on the general model, Slutsky cross-price elasticities were positive between Syria and Jordan, between Syria and Turkey, between Egypt and ROW, between Turkey and each of the other sources, between ROW and Syria, and between ROW and Egypt. The cross-price elasticities were negative for other pairs of countries.

Restricted General Model for Onions

Coefficients of the general model with symmetry and homogeneity imposed are shown in Table 24 for onions. All own-price parameters were negative as indicated by theory. All cross-price parameters were positive with the exception of ROW and India and ROW and Turkey. The only own-price parameters that were significant at $\alpha = 0.10$ were for onions imported from India and from ROW.

Table 24. Coefficients of Restricted General Demand Model for Imported Onions.

Country	Intercept	dlnQ	WidlnQ $\delta 1$	India dlnp1	Egypt dlnp2	Turkey dlnp3	ROW dlnp4	wi*(dln(pi)-dlnP) $\delta 2$	P value of F test
India	0.0032	0.0724	1.6897	$\boxed{-0.4498}$	0.2219	0.3775	-0.1496	-2.5522	
P-Value	0.8311	0.3760	<.0001	0.0105	0.0433	0.0143	0.0883	0.0249	<.0001
Egypt	0.0047	0.0472	0.4190	0.2219	$\boxed{-0.4602}$	0.0657	0.1727	0.0110	
P-Value	0.6699	0.7263	0.2687	0.0433	0.1272	0.7483	0.0811	0.9929	0.0178
Turkey	-0.0076	-0.2706	1.4949	0.3775	0.0657	$\boxed{-0.3156}$	-0.1276	-1.4229	
P-Value	0.6840	0.1260	0.0002	0.0143	0.7483	0.3429	0.4193	0.3221	<.0001
ROW	-0.0007	0.0173	1.0711	-0.1496	0.1727	-0.1276	$\boxed{-0.0559}$	-0.7439	
P-Value	0.9403	0.7907	0.0130	0.0883	0.0811	0.4193	0.0034	0.5265	0.0017

Tests of residuals detected no autocorrelation up to fourth-order, except that the model for India showed second-order autocorrelation. Normality tests of the residuals from the general model failed to reject normality.

Parameter Estimates for Specific Models for Onions

For onions, results of the Rotterdam model with the homogeneity and symmetry restrictions imposed are reported in Table 25. All own-price parameter estimates were negative. All were significant at $\alpha = 0.10$, with the exception of onions from ROW. The cross-price parameters were positive except for ROW and India, and ROW and Turkey.

Results for the AIDS model with homogeneity and symmetry imposed are reported in Table 26. All own-price parameter signs were negative except for ROW, but only the coefficient for India was statistically significant at a reasonable level of significance. The cross-price parameters were negative for ROW and India. The others were positive.

The results for the NBR model are reported in Table 27. All own-price parameters except ROW were negative. The parameter for India was significant at $\alpha =$ 0.01, and for Egypt at $\alpha = 0.15$. The others were insignificant at typical levels. Cross-price parameters were negative for India and ROW, Egypt and Turkey, and Turkey and ROW. The others were positive.

The coefficients of the restricted CBS model are reported in Table 28. The own-price coefficients were negative, although only the coefficients for India and Egypt were significant. Cross-price parameters were negative for ROW and India and for ROW and Turkey. The others were positive.

Table 25. Coefficients of Restricted Rotterdam Demand Model for Imported Onions

Countries	Intercept	dlnQ	India dlnp1	Egypt dlnp2	Turkey dlnp3	ROW dlnp4	Model F test	DW Test
India	-0.0284	0.3308	-0.7340	0.2487	0.5050	-0.0197		
P-Value	0.4763	<.0001	<.0001	0.0138	0.0013	0.7655	<.0001	2.2
Egypt	0.0105	0.1870	0.2487	-0.4800	0.0845	0.1468		
P-Value	0.6796	0.0006	0.0138	0.0195	0.6032	0.0614	0.0038	2.2
Turkey	0.0346	0.3321	0.5050	0.0845	-0.4259	-0.1636		
P-Value	0.4229	0.0002	0.0013	0.6032	0.0642	0.0757	0.0008	2.4
ROW	-0.0144	0.1357	-0.0197	0.1438	-0.1636	-0.1009		
P-Value	0.4843	0.0020	0.7655	0.0614	0.0757	0.9337	0.003	2.3

Table 26. Coefficients of Restricted AIDS Demand Model for Imported Onions

Countries	Intercept	dlnQ	India dlnp1	Egypt dlnp2	Turkey dlnp3	ROW dlnp4	Model F test	DW test
India	-0.0078	0.1905	-0.6288	0.1854	0.4683	-0.0248		
P-Value	0.8297	0.0081	<.0001	0.0680	0.0014	0.6976	<.0001	2.2
Egypt	0.0096	-0.1458	0.1854	-0.3190	0.0103	0.1234		
P-Value	0.7152	0.0084	0.0680	0.1356	0.9511	0.1359	0.005	2.2
Turkey	0.0002	-0.0708	0.4683	0.0103	-0.2964	-0.1821		
P-Value	0.9960	0.3699	0.0014	0.9511	0.1756	0.0414	0.0983	2.4
ROW	-0.0005	0.0179	-0.0248	0.1234	-0.1821	0.0565		
P-Value	0.9816	0.6635	0.6976	0.1359	0.0414	0.4170	0.3452	2.4

Table 27. Coefficients of Restricted NBR Demand Model for Imported Onions

Countries	Intercept	dlnQ	India dlnp1	Egypt Dlnp2	Turkey dlnp3	ROW dlnp4	Model F test	DW test
India	-0.0305	0.3293	-0.6336	0.2093	0.4473	-0.0230		
P-Value	0.4320	<.0001	<.0001	0.0396	0.0035	0.7256	<.0001	2.2
Egypt	0.0086	0.1888	0.2093	-0.2973	-0.0283	0.1163		
P-Value	0.7417	0.0007	0.0396	0.1527	0.8650	0.1449	0.0223	2.3
Turkey	0.0356	0.3309	0.4473	-0.0283	-0.2159	-0.2032		
P-Value	0.4070	0.0002	0.0035	0.8650	0.3446	0.0286	0.0011	2.4
ROW	-0.0011	0.1373	-0.0230	0.1163	-0.2032	0.0691		
P-Value	0.5809	0.0017	0.7256	0.1449	0.0286	0.3309	0.0024	2.4

Table 28. Coefficients of Restricted CBS Demand Model for Imported Onions

Countries	Intercept	dlnQ	India dlnp1	Egypt dlnp2	Turkey dlnp3	ROW dlnp4	Model F test	DW test
India	-0.0057	0.1920	-0.7294	0.2239	0.5270	-0.0215		
P-Value	0.8786	0.0095	<.0001	0.0278	0.0005	0.7386	<.0001	2.3
Egypt	0.0116	-0.1477	0.2239	-0.4984	0.1202	0.1543		
P-Value	0.6562	0.0070	0.0278	0.0197	0.4684	0.0600	0.0006	2.2
Turkey	-0.0004	-0.0694	0.5270	0.1202	-0.5047	-0.1425		
P-Value	0.9456	0.6047	0.1193	0.7239	0.4593	0.4162	0.0476	2.4
ROW	-0.0015	0.0163	-0.0215	0.1543	-0.1425	-0.0185		
P-Value	0.8597	0.6910	0.7386	0.0600	0.4162	0.7906	0.5413	2.3

Elasticities for Onions – Restricted Demand Systems

Expenditure Elasticities

The import expenditure elasticities for onions under the five models are shown in Table 29. The results indicate that regardless of the model, import expenditure elasticities from India and ROW were greater than unity. For Egypt and Turkey, the expenditure elasticities for all demand systems fell somewhere between 0 and 1.

For the general model, the expenditure elasticity for imported onions from India was 2.09, which means that imported onions from India were considered much like luxury goods. On the other hand, expenditure elasticities for Egypt and Turkey were 0.57 and 0.82, respectively.

Own-Price Elasticities for Imported Onions

Slusky own-price elasticities for imported onions were negative, with magnitudes (absolute value) greater than one for India, Egypt, and Turkey for all models. Own-price elasticities for ROW were more variable, although the elasticity for the general model was -1.26. Both Slusky and Cournot own-price elasticities had the same signs. Recall that Cournot own-price elasticities were calculated by holding nominal expenditures constant, so that the elasticities were only affected by price and real income. As a result, the Cournot elasticities estimates are typically more negative than the corresponding Slusky estimates.

Table 29. Own, Cross-Price and Expenditure Elasticites of Restricted Demand Equations of Imported Onions.

			Slutsky Own Price and Cross Price Elasticities Sii and Sij				Cournot Own Price and Cross Price Elasticities Cii and Cij			
Countries	Model	Expenditure Elasticities	India	Egypt	Turkey	ROW	India	Egypt	Turkey	ROW
India	Rotterdam	1.8475	-4.09533	1.38875	2.82004	-0.11023	-4.4262	1.0579	2.4892	-0.4411
	Aids	2.0637	-4.33223	1.34400	3.01768	-0.02950	-4.7018	0.9744	2.6481	-0.3991
	NBR	1.8389	-4.35881	1.47738	2.90083	-0.01939	-4.6881	1.1481	2.5715	-0.3487
	CBS	2.0724	-4.07295	1.25016	2.94291	-0.12011	-4.4441	0.8790	2.5718	-0.4912
	General	2.0942	-5.0641	-1.3132	-0.4440	-3.3874	-5.5931	-1.7213	-0.2595	-3.3374
Egypt	Rotterdam	0.6055	0.80536	-1.55445	0.27362	0.47546	0.6184	-1.7414	0.0866	0.2885
	Aids	0.5280	0.77941	-1.72428	0.43619	0.50869	0.6164	-1.8873	0.2731	0.3457
	NBR	0.6113	0.85676	-1.65398	0.31136	0.48586	0.6680	-1.8428	0.1226	0.2971
	CBS	0.5217	0.72499	-1.61400	0.38930	0.49971	0.1923	-2.1467	-0.1434	-0.0330
	General	0.5718	0.7295	-1.4793	0.2238	0.5701	0.6251	-1.6593	-0.0111	0.4206
Turkey	Rotterdam	0.8242	1.25344	0.20971	-1.05702	-0.40613	0.9214	-0.1224	-1.3891	-0.7382
	Aids	0.8242	1.34129	0.33432	-1.33278	-0.34281	1.0092	0.0022	-1.6649	-0.6749
	NBR	0.8213	1.28935	0.23864	-1.13288	-0.39510	0.9584	-0.0923	-1.4638	-0.7260
	CBS	0.8277	1.30805	0.29838	-1.25265	-0.35378	0.3781	-0.6315	-2.1826	-1.2837
	General	0.8234	-0.4858	-1.2598	-2.2061	-1.7397	-0.3785	-1.0747	-1.9646	-1.9166
ROW	Rotterdam	1.2426	-0.18075	1.34440	-1.49830	-0.92390	-0.3308	1.1943	-1.6484	-1.0740
	Aids	1.1639	-0.04837	1.43838	-0.01967	-0.37348	-0.1837	1.3031	-0.1550	-0.5088
	NBR	1.2572	-0.03180	1.37383	-1.45763	-0.25833	-0.1828	1.2228	-1.6086	-0.4093
	CBS	1.1494	-0.19696	1.41298	-1.30519	-0.16894	-0.3225	1.2874	-1.4307	-0.2945
	General	1.2293	-2.1134	0.8370	-1.9126	-1.2560	-2.2004	0.6871	-1.4759	-1.3091

Cross-Price Elasticity Estimates

Cross-price elasticities for onions are also reported in Table 29. The Slutsky cross-price elasticities were positive for all models and for all country pairs except ROW and India, ROW and Turkey, and India and ROW. The Cournot cross-price elasticities represent the same thing except that nominal, rather than real, expenditure are held constant. Conditional cross-price elasticities were calculated for imported tomatoes, and onions to Saudi Arabia. Positive Slutsky cross-price elasticities in this study indicate that the product from one country is a substitute for the product from the other. On the other hand, a negative sign indicates a complementary relationship between the commodity from one country and the same product from the other country.

Elasticity Estimates for Onions – Unrestricted Demand Systems

For onions, the results in Table 30 show that for expenditure, own-price, and cross-price elasticities under the unrestricted model are very similar to the results for the restricted model (Table 29) . The exception is that cross-price elasticity under the unrestricted model is relatively higher for the general model than for the other models. Also, as with the restricted model, many of the cross-price elasticities have negative signs.

Table 30. Own, Cross-Price and Expenditure Elasticities of Unrestricted Demand Equations for Imported Onions.

Countries	Models	Expenditure Elasticities	Slutsky Own Price and Cross Price Elasticities Sii and Sij				Cournot Own Price and Cross Price Elasticities Cii and Cij			
			India	Egypt	Turkey	ROW	India	Egypt	Turkey	ROW
India	Rotterdam	1.5496	-4.42162	1.46104	0.56805	-1.13859	-4.6991	1.1835	0.2905	-1.4161
	AIDS	1.7909	-4.59183	1.96426	0.94604	-0.95366	-4.9126	1.6435	0.6253	-1.2744
	NBR	1.5666	-4.64594	1.42118	0.85151	-0.97365	-4.9265	1.1406	0.5710	-1.2542
	CBS	1.7738	-4.36751	2.00451	0.66241	-1.11849	-4.6852	1.6868	0.3448	-1.4361
	General	2.1061	-6.9213	-6.1757	-6.4778	-7.2010	-6.3545	-5.5072	-4.7224	-6.7252
Egypt	Rotterdam	0.6183	0.81982	-1.40364	0.60208	0.47022	0.6289	-1.5946	0.4112	0.2793
	AIDS	0.5713	0.78362	-1.61003	1.06278	0.61326	0.6072	-1.7865	0.8863	0.4368
	NBR	0.6278	0.88242	-1.46217	0.68899	0.48678	0.6885	-1.6561	0.4951	0.2929
	CBS	0.5618	0.72089	-1.55124	0.97571	0.59655	0.5474	-1.7247	0.8022	0.4231
	General	0.59290	3.4630	-1.5414	3.7450	3.0694	2.9320	-1.4571	2.5504	2.2610
Turkey	Rotterdam	1.0289	1.43563	-0.07716	0.59358	0.28089	1.0211	-0.4917	0.1790	-0.1337
	AIDS	0.9822	1.48764	0.03134	-0.07652	0.18374	1.0919	-0.3644	-0.4722	-0.2120
	NBR	1.0188	1.45862	0.05284	0.47704	0.27258	1.0481	-0.3576	0.0666	-0.1379
	CBS	0.9923	1.46466	-0.09831	0.04011	0.19203	1.0649	-0.4981	-0.3597	-0.2078
	General	0.93068	-3.8330	-5.5225	-2.5726	-4.9769	-3.1772	-4.3916	-1.0971	-2.6285
ROW	Rotterdam	1.0714	-0.36407	1.85863	-4.82500	-0.49931	-0.4811	1.7416	-4.9420	-0.6163
	AIDS	0.9810	-0.17418	1.21543	-4.27348	-0.84787	-0.2813	1.1083	-4.3806	-0.9550
	NBR	1.0540	-0.25769	1.61113	-5.10591	-0.78603	-0.3728	1.4960	-5.2210	-0.9011
	CBS	0.9985	-0.28001	1.46168	-0.39930	-0.56094	-0.3891	1.3526	-0.5084	-0.6700
	General	3.30634	-0.9840	0.5720	-5.2705	-0.7974	-1.4622	-0.2525	-5.7365	-1.0890

The Cournot and Slutsky own and cross-price elasticities for imported onions were mostly consistent. All the own-price elasticities were negative.

Cross-price elasticities indicated that onions from Egypt and all other sources, and ROW and Egypt, were substitutes for each other, and that onions from India, and all other sources, and ROW and all other sources except Egypt were complements for each other.

These results from tomatoes and onions can be better understood by graphing them. Figures 15 - 21 use the estimated elasticities from the unrestricted models to show the effects on quantity of tomatoes demanded resulting from changes in expenditures or prices. Figures 22 – 27 show those same effects for onions using the restricted models. The focus here is on the general unrestricted model for tomatoes, and the general restricted model for onions, since those are most consistent with econometric tests.

Figure 15 shows that if Saudi Arabian consumers increase expenditures on imported tomatoes, a bigger proportion of those increased expenditures will go for Syrian tomatoes than will go to tomatoes from any other single source, although an even larger proportion would go to the countries grouped together in ROW. The expenditure elasticities are lower for Jordan and Egypt, and lowest for Turkey. However, this is an instance in which results from the four specific models differ markedly from the results of the general model.

Figure 16 shows that as price of each of the sources of tomatoes imported by Saudi Arabia increases, quantity of tomatoes demanded from Jordan decreases the most, followed by Egypt. For the same percentage increase in price, there are smaller reductions in quantity of tomatoes demanded from Syria, Turkey, and ROW.

Figures 17-21 show the effects on demand for tomatoes from each source as the price of tomatoes from other sources increases. Figure 17 shows that demand for Syrian tomatoes is affected very little from price increases for tomatoes from the other sources.

Figure 18 shows a large decrease in demand for Jordanian tomatoes when prices in other countries increase. This is unexpected, since it indicates that tomatoes from Jordan are complements with tomatoes from other sources. Figure 19 indicates that as price of Egyptian tomatoes increases, demand for tomatoes from ROW increases, but demand for tomatoes from Syria, Jordan, and Turkey decreases. Again, this latter result is unexpected.

Figure 20 indicates that as price of Turkish tomatoes increases, demand for tomatoes from all the other sources increases. This indicates that Turkish tomatoes are substitutes for tomatoes from the other sources. Figure 21 indicates that as price of tomatoes from ROW increases, demand for tomatoes from Syria and Egypt increases, while demand for tomatoes from Jordan and Turkey decreases slightly.

Effects on demand or quantity demanded for onions resulting from changes in expenditures and prices are shown in Figure 22 – 27. Figure 22 indicates that as expenditures on imported onions increase, the biggest proportion of those expenditures goes for purchases of Indian onions. An increase about half that size goes to onions from ROW, while expenditures increase less for onions from Egypt and Turkey. Apparently, onions from India behave much like a luxury good.

Figure 23 shows that as the price of onions from these sources increase by 1%, quantity of Indian onions demanded decreases the most. Quantity of onions demanded from other sources also decreases as prices of onions from those sources increases, with the percentage decrease in quantity greater than the percentage decrease in price, but the effect is much less elastic for onions from Egypt, Turkey, and ROW than it is for onions from India.

Figure 24 shows that Indian onions are complements to onions from other sources. As their price increases, demand for onions from other sources also decreases. In contrast, Figure 25 shows that Egyptian onions are substitutes with onions from other sources. As price of Egyptian onions increases, demand for onions from other sources increases.

Figure 26 shows that, much like Indian onions, Turkish onions are complements with onions from other sources. Figure 27 shows that there is a substitute relationship between onions from ROW and onions from Egypt, but a complementary relationship between onions from ROW and onions from India and Turkey.

Conclusions

Five demand systems were used to investigate demand for Saudi Arabian imports of fresh tomatoes and onions from five different countries. The demand systems considered were Rotterdam, AIDS, NBR, CBS and a general model. The purpose of this study was to better understand the likely effects of price and trade liberalization on domestic markets as well as on demand for imports. All models were estimated using SAS with the SUR option, and homogeneity and symmetry conditions were tested.

Statistical tests indicated that none of the specific models fit the data very well, so conclusions were drawn from estimates of the general model. Moreover, symmetry and homogeneity restrictions did not hold for tomatoes using the general model. Thus, Demand for Turkish and ROW tomatoes was inelastic, so the effect would be the opposite.

The level of substitutability between Syrian tomatoes and tomatoes from other sources is low, indicating that changes of prices or tariffs on tomatoes from other sources would have little impact on demand for Syrian tomatoes. However, if prices of, or tariffs on, Syrian tomatoes increases, there would be some benefit for Turkish tomatoes, but there would actually be a negative impact on demand for tomatoes from Jordan and Egypt. The results also suggest that Egyptian tomatoes are complementary with tomatoes from Syria, Jordan, and Turkey. This may result from Egyptian tomatoes being used for different, but complementary, uses than tomatoes from other sources, such as in salads.

The model for onions seemed to work better than the model for tomatoes. This may be because imported onions made up 66% of Saudi expenditures for onions during the span of this study, whereas imported tomatoes made up only 13% of Saudi expenditures for tomatoes.

The results for onions indicate that as expenditures on imported onions increase, producers and importers of Indian onions will benefit the most. Onions from India are also the most price elastic, suggesting that a decrease in tariffs on Indian tomatoes will result in a large increase in quantity demanded. Conversely, attempts to retain a high tariff on Indian onions will have a bigger negative impact on quantity demanded than similar tariffs applied to onions from other sources. However, own-price elasticities of demand for onions from all sources were elastic, indicating that changes in tariffs on onions from any source will have a large impact on quantities of imported onions demanded.

The average price of Indian onions was 0.75 SR/kg, the prices for Egyptian and Turkish onions were 0.65 SR/kg, and the price for ROW onions was 0.99 SR/kg. Over the same time period the average expenditure share of imported onions was 40% for Indian onions, 31% for Egyptian onions, 18% for Turkish onions, and 11% for ROW onions. This suggests that Saudis prefer Indian onions, which is supported by the high expenditure and own-price elasticities of demand.

These results can also give insight to domestic producers. It is clear from these results that when Saudi consumers increase expenditures on imported tomatoes or onions, they spend much of that increase on Syrian tomatoes and Indian onions. If domestic producers can produce and market vegetables with similar characteristics they may be able to capture a portion of the expected increase in expenditures that would otherwise be spent on imported vegetables.

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APPENDIX

Table 31. Coefficients of Unrestricted Rotterdam Demand Model for Imported Onions

Countries	Intercept	dlnQ	India dlnp1	Egypt dlnp2	Turkey dlnp3	ROW dlnp4	Model F test	DW test
India	-0.0282	0.2775	-0.7918	0.2616	0.1017	-0.2039		
P-Value	0.4843	0.0018	<.0001	0.4742	0.7886	0.1797	<.0001	2.18
Egypt	0.0114	0.1909	0.2532	-0.4335	0.1859	0.1452		
P-Value	0.6568	0.0008	0.0167	0.0667	0.4437	0.1351	0.0106	2.22
Turkey	0.0329	0.4145	0.5784	-0.0311	0.2392	0.1132		
P-Value	0.4485	<.0001	0.0016	0.9372	0.5606	0.4885	0.0002	2.57
ROW	-0.0162	0.1170	-0.0398	0.2030	-0.5269	-0.0545		
P-Value	0.4312	0.0093	0.6314	0.2804	0.0087	0.4816	0.0010	2.47

Table 32. Coefficients of Unrestricted AIDS Demand Model for Imported Onions

Countries	Intercept	dlnQ	India dlnp1	Egypt dlnp2	Turkey dlnp3	ROW dlnp4	Model F test	DW test
India	-0.0062	0.1416	-0.6753	0.2965	0.0973	-0.1903		
P-Value	0.8640	0.0710	<.0001	0.3729	0.7780	0.1684	<.0001	2.2
Egypt	0.0101	-0.1324	0.1867	-0.2837	0.2038	0.1557		
P-Value	0.7003	0.0208	0.0827	0.2393	0.4152	0.1202	0.0038	2.2
Turkey	-0.0015	-0.0072	0.5272	-0.1118	0.2097	0.0300		
P-Value	0.9710	0.9339	0.0022	0.7637	0.5880	0.8451	0.0538	2.59
ROW	-0.0024	-0.0021	-0.0386	0.0990	-0.5107	0.0047		
P-Value	0.9040	0.9611	0.6340	0.5888	0.0093	0.9506	0.1245	2.51

Table 33. Coefficients of Unrestricted NBR Demand Model for Imported Onions

Countries	Intercept	dlnQ	India dlnp1	Egypt dlnp2	Turkey dlnp3	ROW dlnp4	Model F test	DW test
India	-0.0304	0.2806	-0.6850	0.1992	0.0803	-0.1939		
P-Value	0.4362	0.0012	<.0001	0.5751	0.8277	0.1895	<.0001	2.18
Egypt	0.0096	0.1939	0.2172	-0.2381	0.0883	0.1166		
P-Value	0.7126	0.0009	0.0424	0.3178	0.7205	0.2373	0.0197	2.27
Turkey	0.0343	0.4105	0.5155	-0.1031	0.4328	0.0658		
P-Value	0.4258	<.0001	0.0042	0.7921	0.2900	0.6841	0.0003	2.58
ROW	-0.0135	0.1151	-0.0477	0.1422	-0.6016	0.0114		
P-Value	0.5110	0.0102	0.5638	0.4467	0.0029	0.8820	0.0005	2.5

Table 34. Coefficients of Unrestricted CBS Demand Model for Imported Onions

Countries	Intercept	dlnQ	India dlnp1	Egypt dlnp2	Turkey dlnp3	ROW dlnp4	Model F test	DW test
India	-0.0039	0.1386	-0.7821	0.3590	0.1186	-0.2003		
P-Value	0.9175	0.0861	<.0001	0.2959	0.7387	0.1598	<.0001	2.22
Egypt	0.0119	-0.1353	0.2226	-0.4790	0.3013	0.1842		
P-Value	0.6279	0.0172	0.0378	0.0475	0.2255	0.0646	0.0004	2.17
Turkey	0.0029	-0.0031	0.5901	-0.0396	0.0162	0.0774		
P-Value	0.9447	0.9716	0.0007	0.9159	0.9670	0.6187	0.0262	2.5
ROW	-0.0052	-0.0002	-0.0306	0.1596	-0.0436	-0.0613		
P-Value	0.7971	0.9970	0.7059	0.3846	0.0252	0.4192	0.2931	2.3

Table 35. Coefficients of Unrestricted Rotterdam Demand Model for Imported Tomatoes

Countries	Intercept	dlnQ	Syria dlnp1	Jordan dlnp2	Egypt dlnp3	Turkey dlnp4	ROW dlnp5	Model F test	DW test
Syria	0.1448	0.6339	-0.4836	0.4234	0.0698	0.4987	-0.3817		
P-Value	0.0445	<.0001	0.0021	0.0419	0.7541	0.0441	0.0718	<.0001	2.35
Jordan	0.0112	-0.0150	0.0094	-0.1038	0.0226	-0.0810	-0.2614		
P-Value	0.8383	0.6146	0.9352	0.5125	0.8960	0.6678	0.1106	0.5925	1.94
Egypt	-0.0957	0.1179	0.0277	-0.2445	-0.1380	-0.1069	0.5541		
P-Value	0.1115	0.0002	0.8267	0.1676	0.4621	0.6010	0.0025	0.0118	2.25
Turkey	0.0471	0.1979	0.4532	-0.0725	0.0243	-0.3000	0.1464		
P-Value	0.4429	<.0001	0.0009	0.6814	0.8998	0.1574	0.4191	<.0001	2.09
ROW	-0.0133	0.0654	-0.0068	0.0026	0.0213	-0.0107	-0.0574		
P-Value	0.5714	<.0001	0.8917	0.9699	0.7732	0.8939	0.4084	<.0001	2.42

Table 36. Coefficients of Unrestricted AIDS Demand Model for Imported Tomatoes

Countries	Intercept	dlnQ	Syria dlnp1	Jordan dlnp2	Egypt dlnp3	Turkey dlnp4	ROW dlnp5	Model F test	DW test
Syria	0.0366	0.2438	0.1418	0.1541	0.0450	-0.0286	-0.3812		
P-Value	0.5958	<.0001	0.3355	0.4399	0.8360	0.9041	0.0653	<.0001	2.8
Jordan	0.0063	-0.1062	-0.4947	-0.0689	-0.0599	0.0841	-0.5651		
P-Value	0.9174	0.0022	0.0003	0.6960	0.7557	0.6886	0.0027	0.0001	1.79
Egypt	0.0157	-0.0284	-0.1831	-0.2052	0.0656	0.1924	0.8313		
P-Value	0.8384	0.4997	0.2670	0.3583	0.7872	0.4691	0.0006	0.0001	2.21
Turkey	-0.0528	0.0328	0.3786	0.0708	0.6964	0.0020	0.1722		
P-Value	0.3169	0.2525	0.0012	0.7075	0.6738	0.9913	0.2688	0.0152	2.12
ROW	-0.0059	-0.1421	0.1574	-0.0885	-0.1204	-0.2499	-0.0573		
P-Value	0.8826	<.0001	0.0663	-0.0885	0.3378	0.0711	0.6250	<.0001	2.83

Table 37. Coefficients of Unrestricted NBR Demand Model for Imported Tomatoes

Countries	Intercept	dlnQ	Syria dlnp1	Jordan dlnp2	Egypt dlnp3	Turkey dlnp4	ROW dlnp5	Model F test	DW test
Syria	0.1443	0.6367	0.4029	0.4357	0.0678	0.4913	-0.4199		
P-Value	0.0537	<.0001	0.0123	0.0439	0.7698	0.0559	0.0571	<.0001	2.38
Jordan	0.0132	-0.0189	0.0007	-0.0924	0.0193	-0.0837	-0.2852		
P-Value	0.8990	0.5248	0.9953	0.5576	0.9106	0.6554	0.0807	0.5292	1.95
Egypt	-0.0968	0.1196	0.0034	-0.2576	-0.1074	-0.1486	0.5611		
P-Value	0.1040	0.0004	0.9780	0.1329	0.5625	0.4633	0.0020	0.0088	2.25
Turkey	-0.0495	0.2035	0.4229	-0.0902	0.0065	-0.1795	0.1418		
P-Value	0.4234	<.0001	0.0020	0.6124	0.9734	0.3965	0.4372	<.0001	2.11
ROW	-0.0112	0.0592	-0.0242	0.0045	0.0139	-0.0795	0.0022		
P-Value	0.5890	<.0001	0.5840	0.9401	0.8319	0.2670	0.9707	<.0001	2.39

Table 38. Coefficients of Unrestricted CBS Demand Model for Imported Tomatoes

Countries	Intercept	dlnQ	Syria dlnp1	Jordan dlnp2	Egypt dlnp3	Turkey dlnp4	ROW dlnp5	Model F test	DW test
Syria	0.0371	0.2409	0.0611	0.1418	0.0699	-0.0212	-0.3430		
P-Value	0.5758	<.0001	0.6649	0.4598	0.8221	0.9258	0.0840	<.0001	2.78
Jordan	0.0043	-0.1023	-0.4859	0.0575	-0.0566	0.0869	-0.5413		
P-Value	0.9177	0.0032	0.0004	0.7450	0.7693	0.6797	0.0040	0.0002	1.76
Egypt	0.0168	-0.0301	0.1589	-0.1921	0.0351	0.2341	0.8243		
P-Value	0.8280	0.4775	0.3364	0.3912	0.8856	0.3805	0.0006	0.0001	2.2
Turkey	-0.0504	0.0276	0.4089	0.0885	0.0875	-0.1186	0.1769		
P-Value	0.3362	0.3385	0.0005	0.5573	0.5951	0.5092	0.2536	0.0073	2.11
ROW	-0.0079	-0.1358	0.1748	-0.0956	-0.1129	-0.1812	-0.1169		
P-Value	0.8285	<.0001	0.0281	0.3670	0.3294	0.1534	0.2816	<.0001	2.7

Figure 1. Saudi Arabian Production of Vegetables, Fruits, and Cereals.

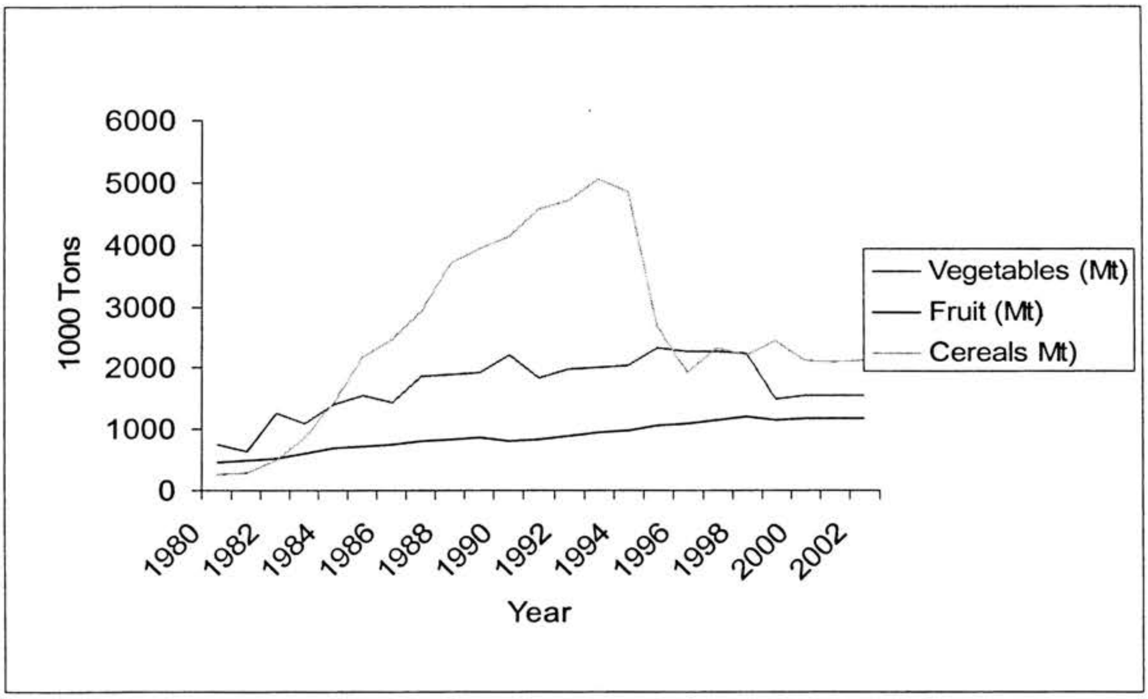


Figure 2. Saudi Arabian Population: 1980-2001(1,000s).

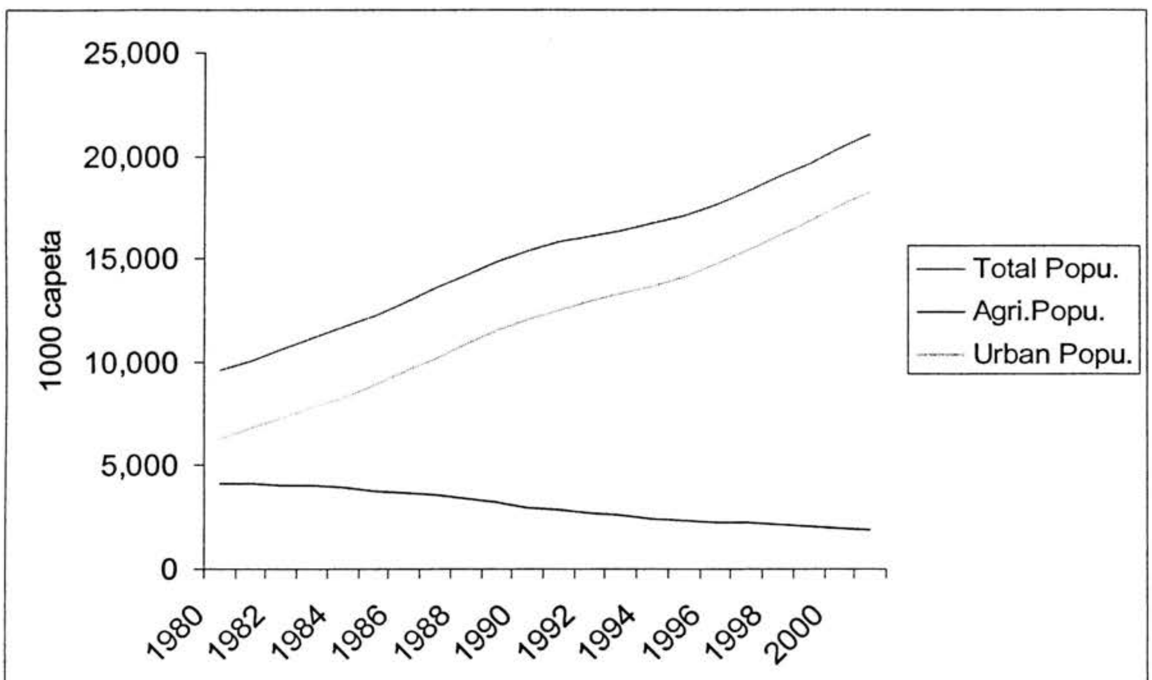


Figure 3. Saudi Arabian Tomatoes Consumption: Domestic, Imported, and Total.

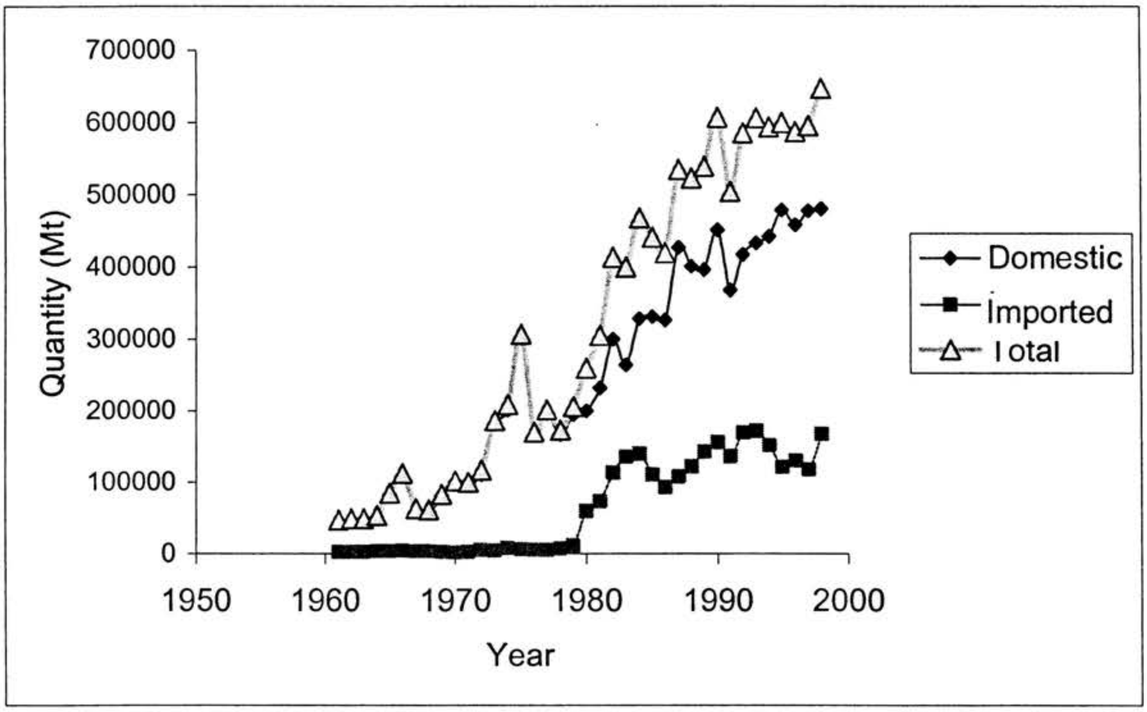


Figure 4. Saudi Arabian Onions Consumption: Domestic, Imported, and Total.

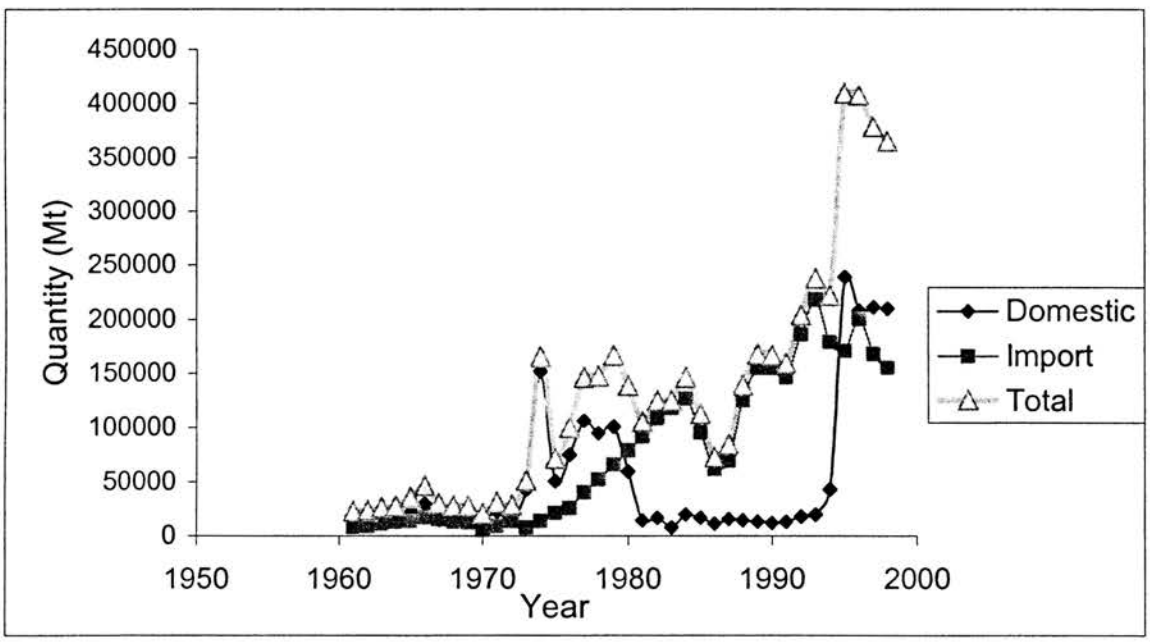


Figure 5. Saudi Arabian Potatoes Consumption: Domestic, Imported, and Total.

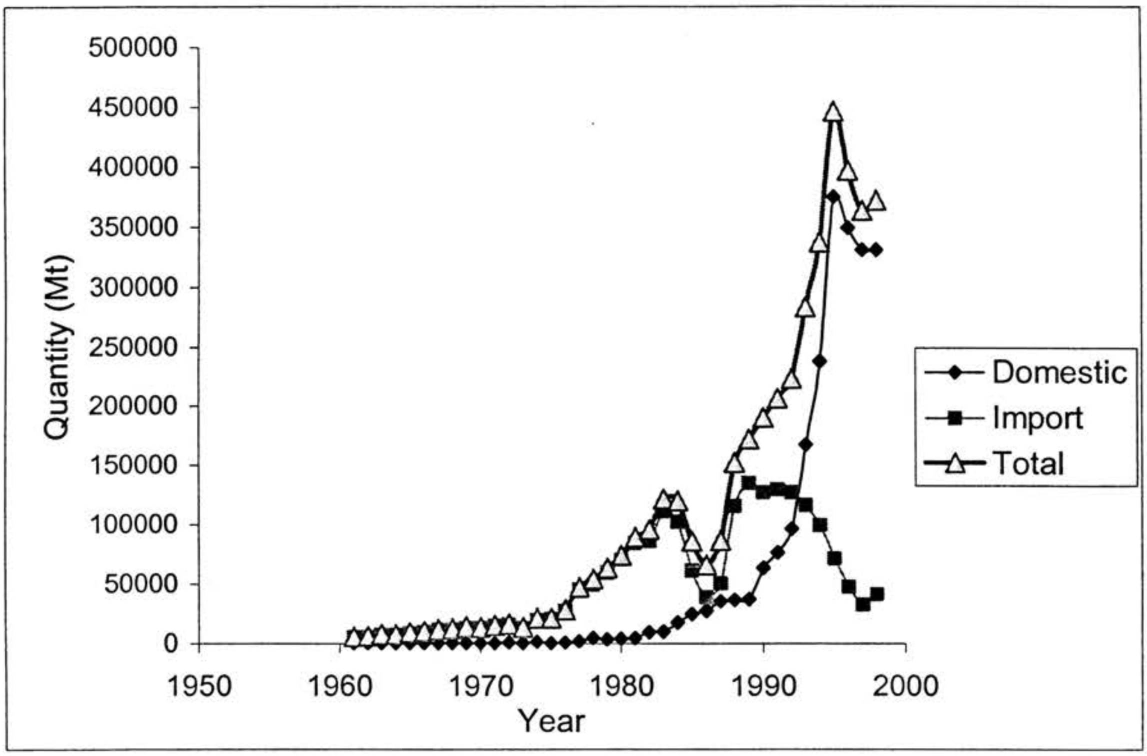


Figure 6. Saudi Arabian Harvested Area of Fruits, Vegetables, and Cereals.

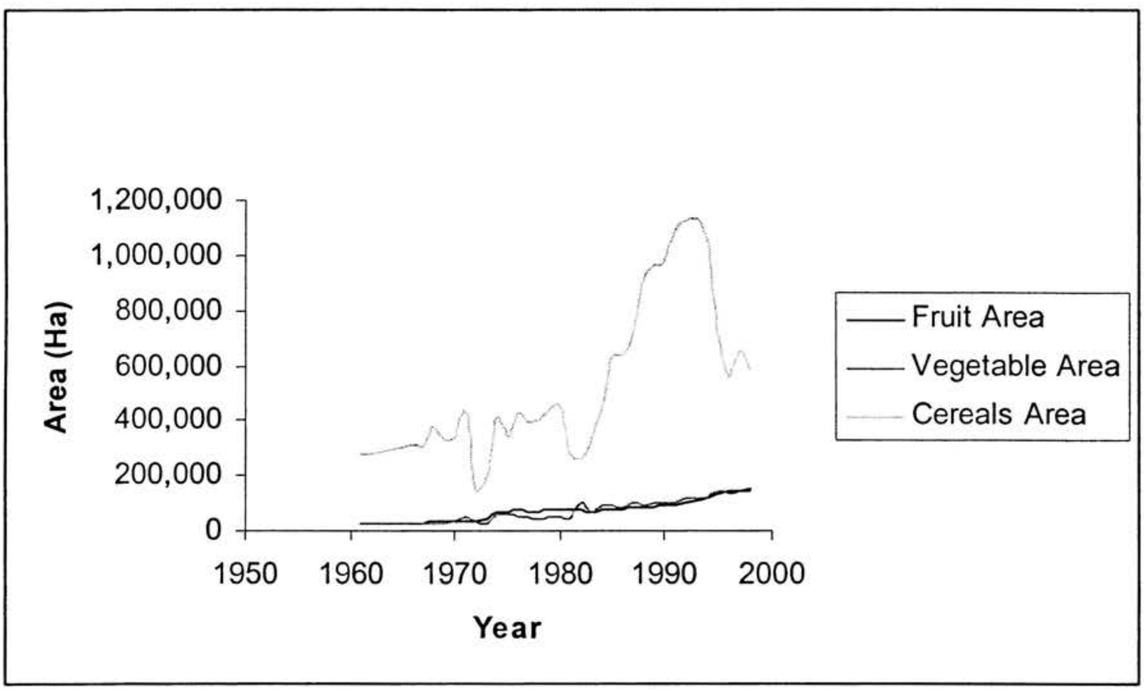


Figure 7. Saudi Arabian Domestic Production of Onions, Potatoes, and Tomatoes.

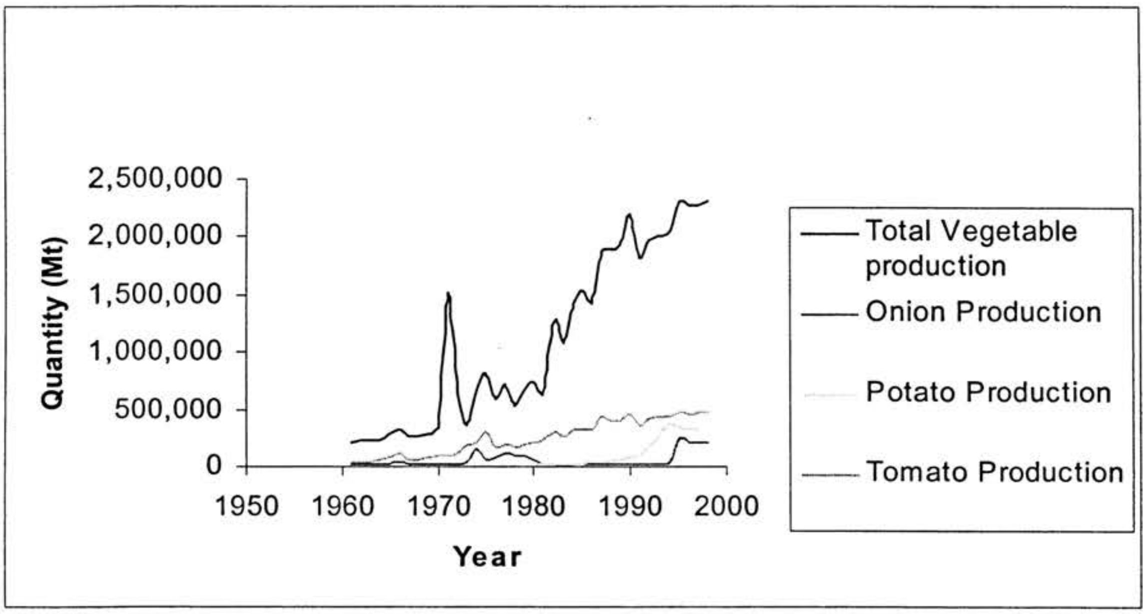


Figure 8. Harvested Area of Onions, Potatoes, and Tomatoes in Saudi Arabian

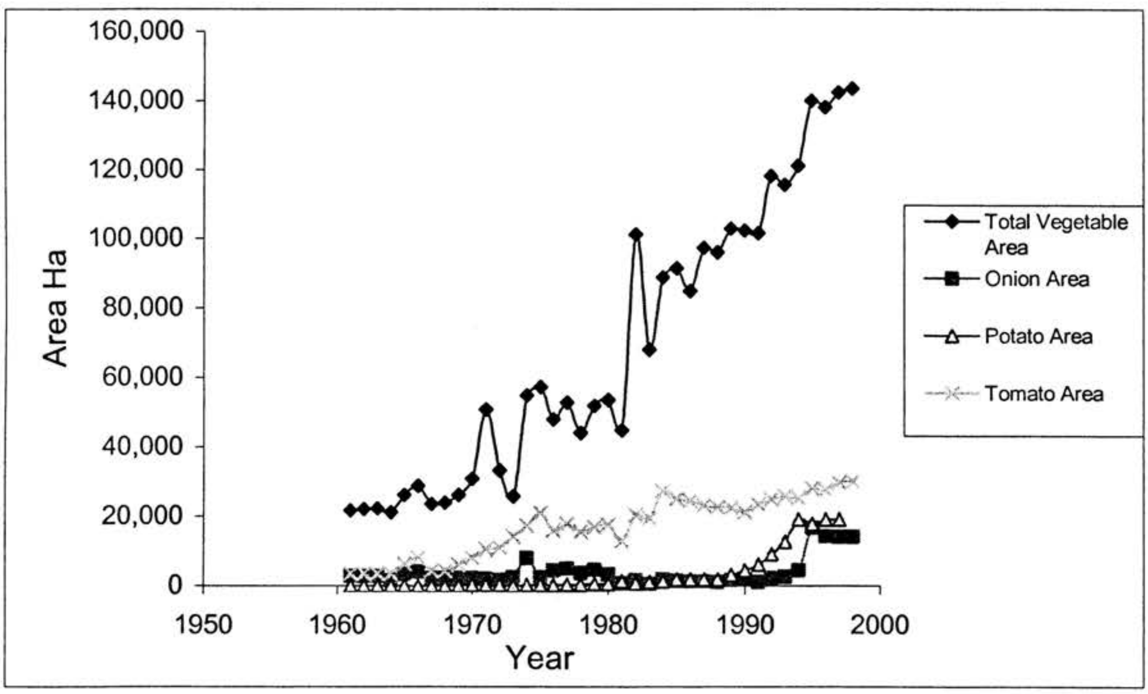


Figure 9. Percentage of Saudi Vegetable Production Accounted for by Onions, Potatoes, and Tomatoes.

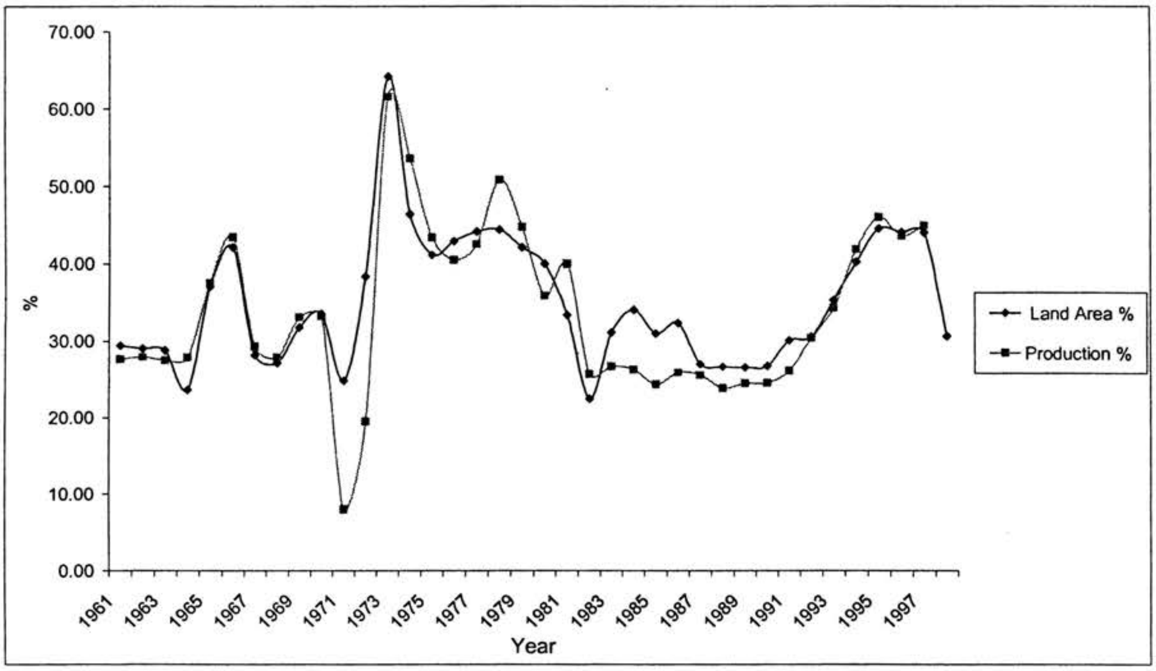


Figure 10. Saudi Vegetable Imports and Domestic Vegetable Production, 1980-2000 (1,000Mt).

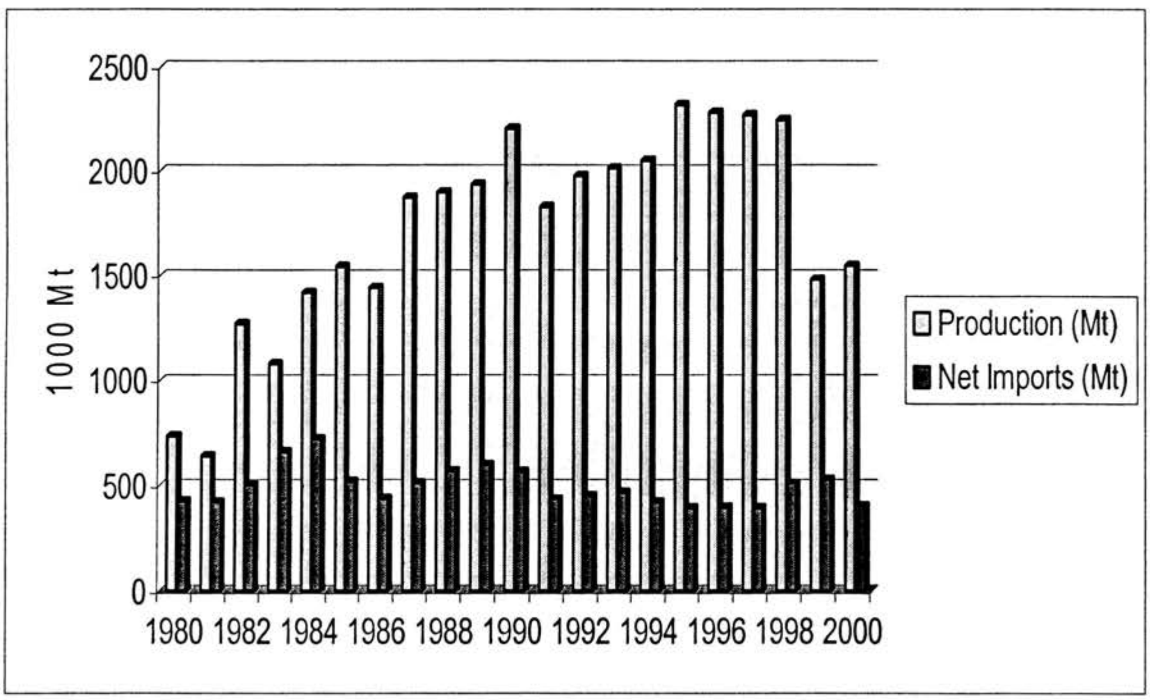


Figure 11. Average Expenditure Share of Imported and Domestic Potatoes, Tomatoes, and Onions in Saudi Arabia, 1980-2000.

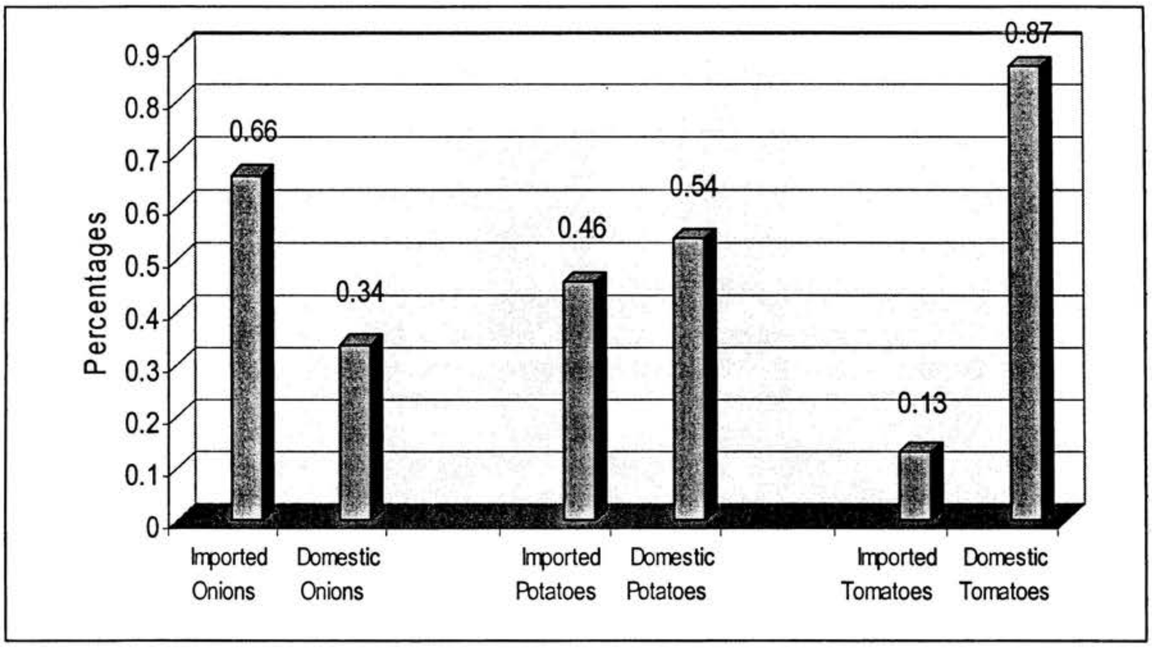


Figure 12. Average Expenditure Shares of Imported Tomatoes, 1988.1-2003.2

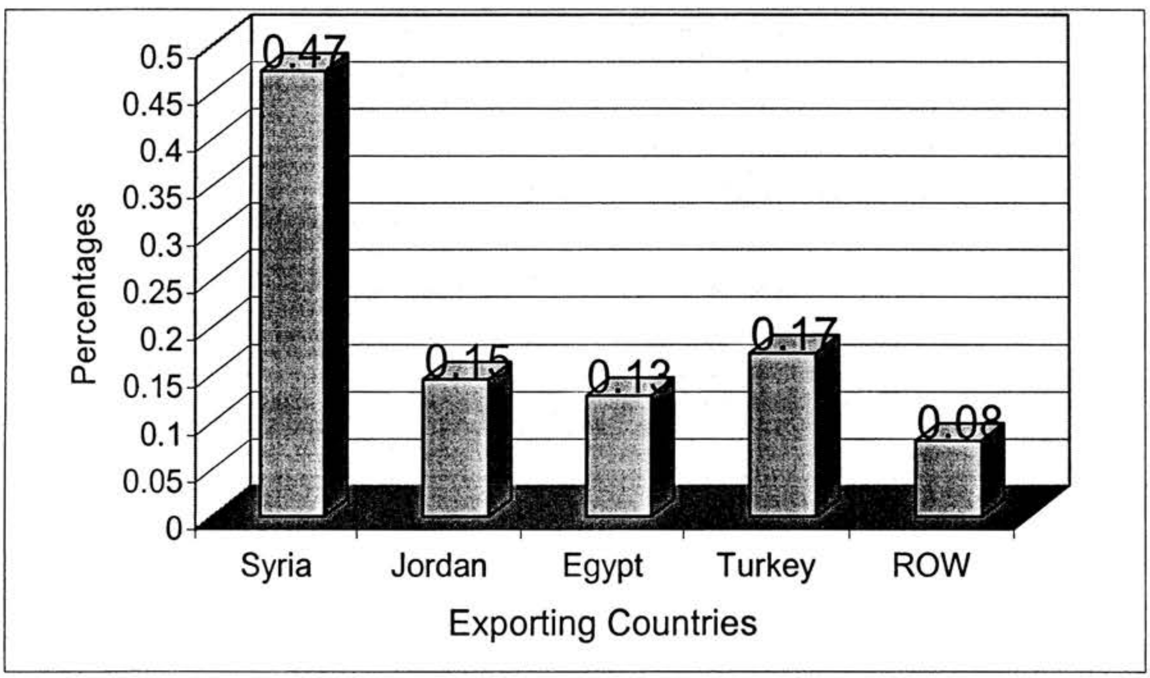


Figure 13. Average Expenditure Shares of Imported Onions, 1988.1-2003.2

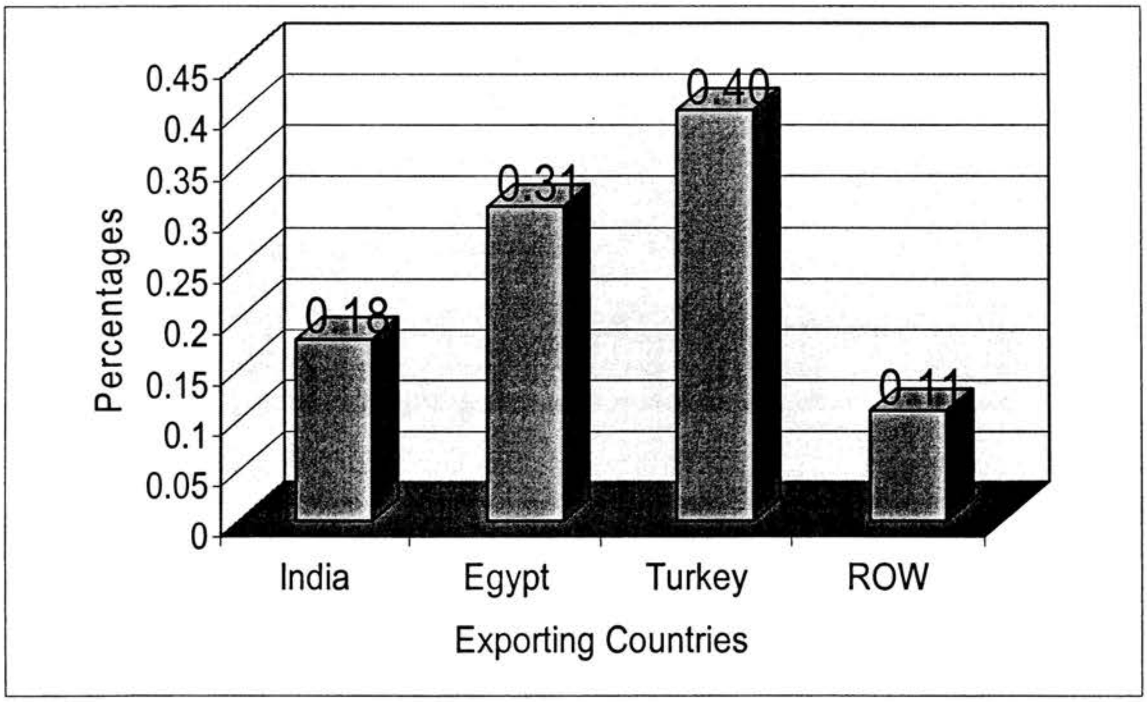


Figure 14. Percentage Change in Quantity Demanded Resulting from a 1% Increase in Expenditures on Imported Tomatoes: Restricted Model.

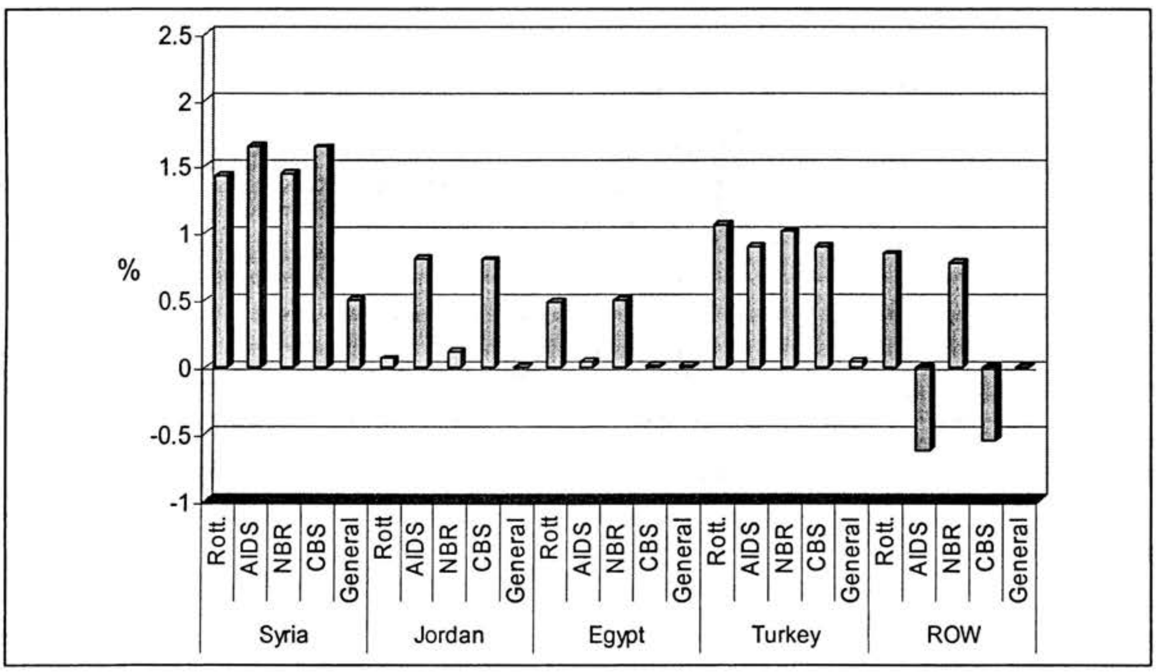


Figure 15. Percentage Change in Quantity Demanded Resulting from a 1% Increase in Expenditures on Imported Tomatoes: Unrestricted Model.

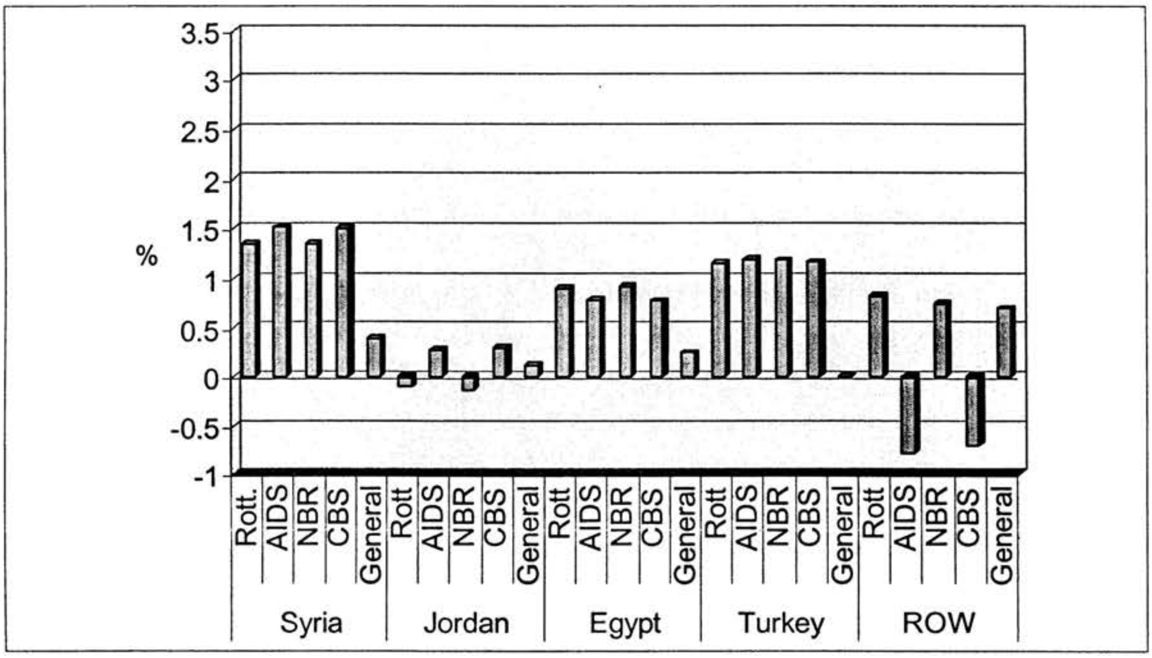


Figure 16. Percentage Change in Quantity of Imported Tomatoes Resulting from a 1% Increase in Price of Tomatoes: Unrestricted Model.

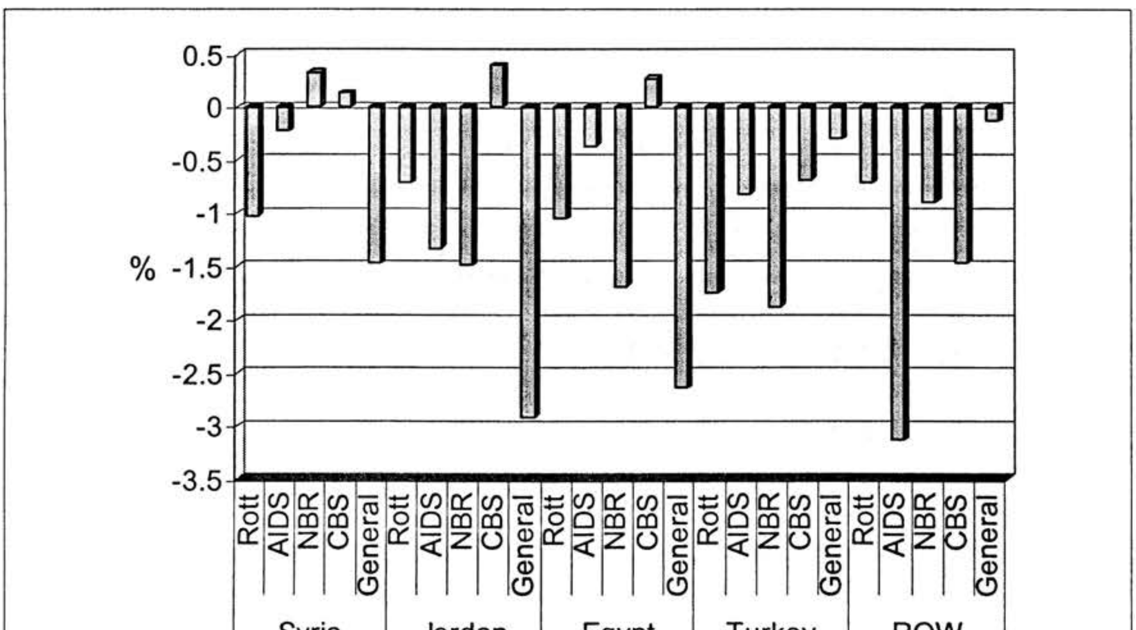


Figure 17. Percentage Change in Quantity of Syrian Tomatoes Demanded Resulting from a 1% Increase in Price of Tomatoes from Other Sources: Unrestricted Model.

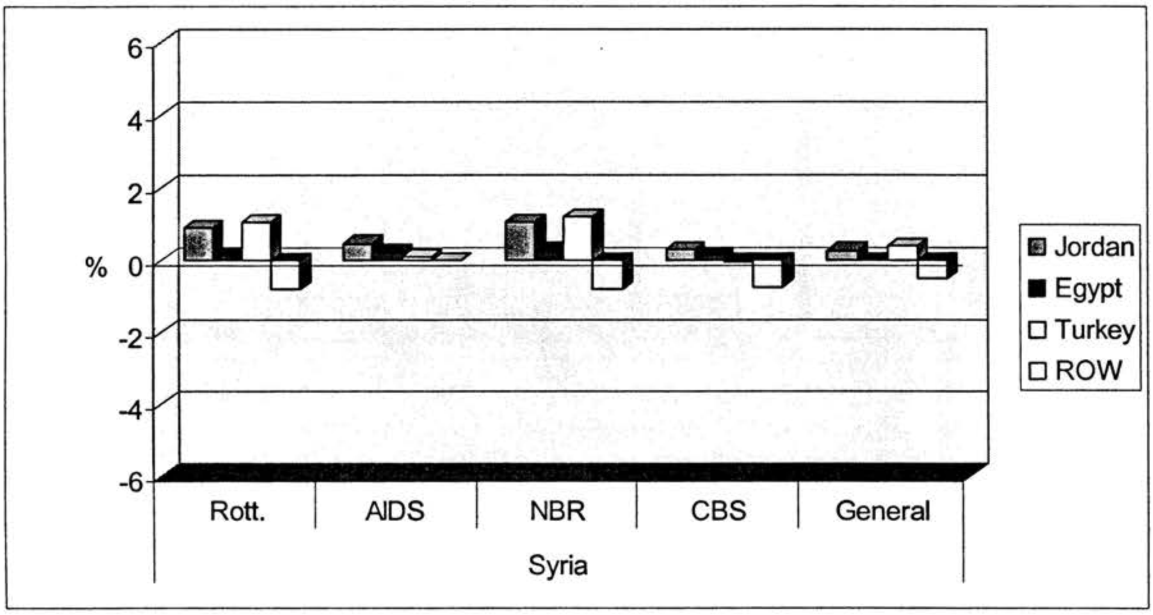


Figure 18. Percentage Change in Quantity of Jordanian Tomatoes Demanded Resulting from a 1% Increase in Price of Tomatoes from Other Sources: Unrestricted Model.

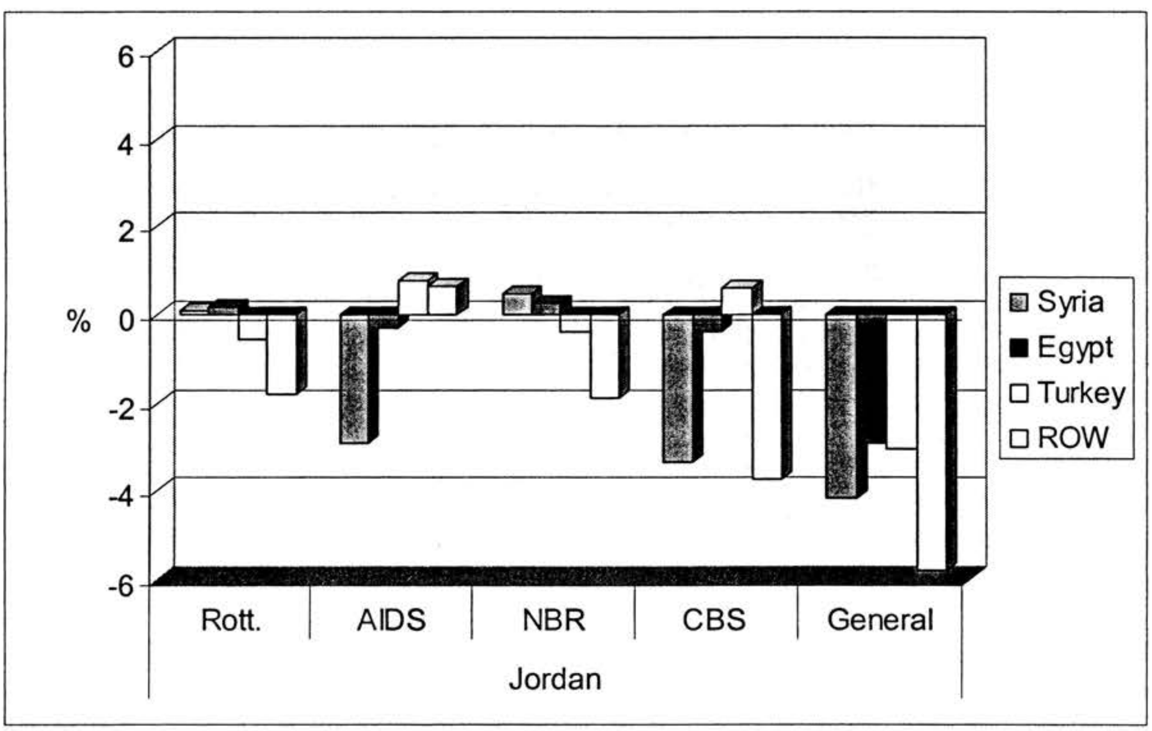


Figure 19. Percentage Change in Quantity of Egyptian Tomatoes Demanded Resulting from a 1% Increase in Price of Tomatoes from Other Sources: Unrestricted Model.

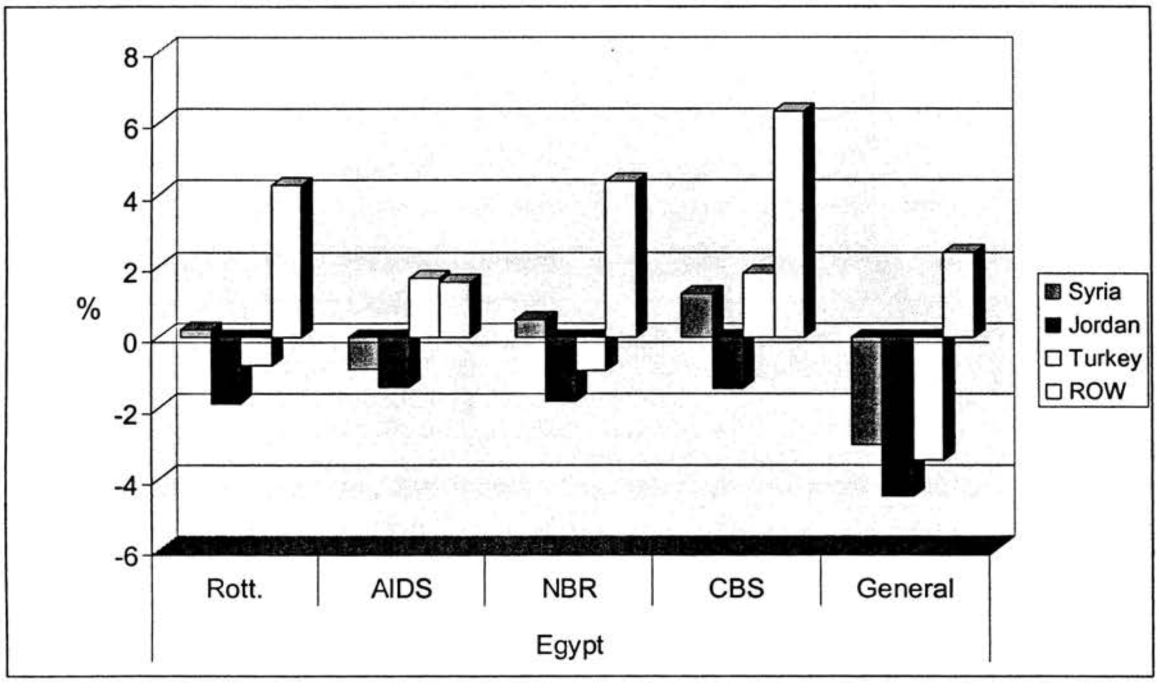


Figure 20. Percentage Change in Quantity of Turkish Tomatoes Demanded Resulting from a 1% Increase in Price of Tomatoes from Other Sources: Unrestricted Model.

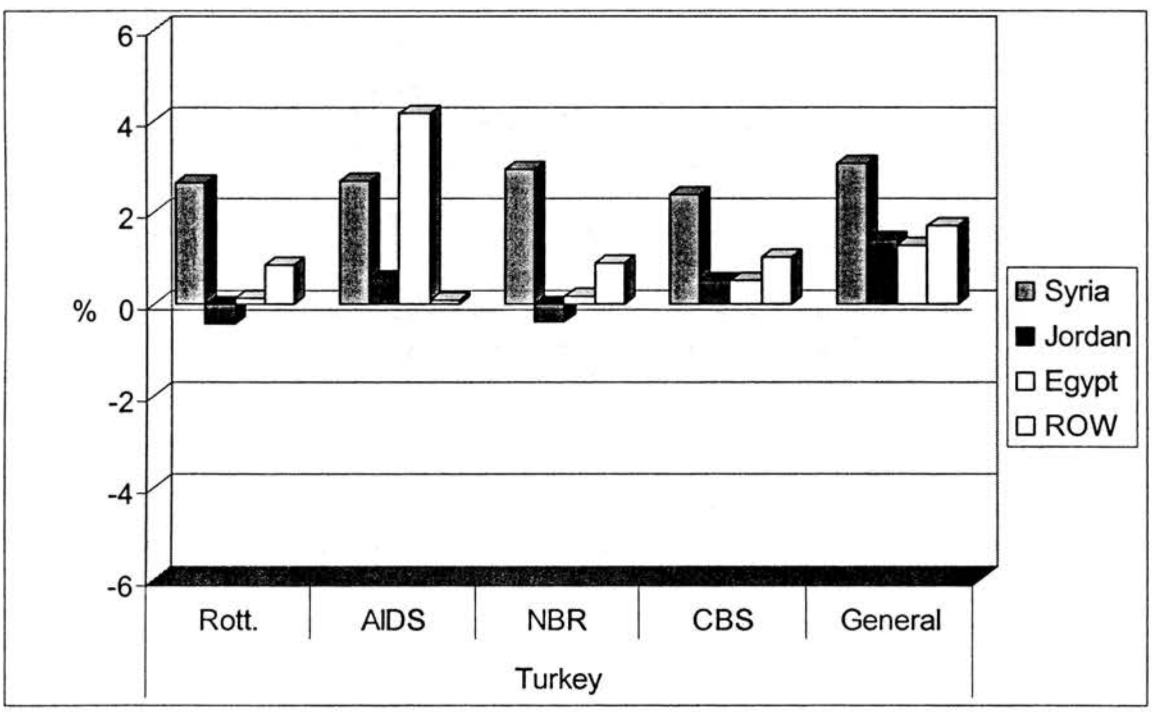


Figure 21. Percentage Change in Quantity of ROW Tomatoes Demanded Resulting from a 1% Increase in Price of Tomatoes from Other Sources: Unrestricted Model.

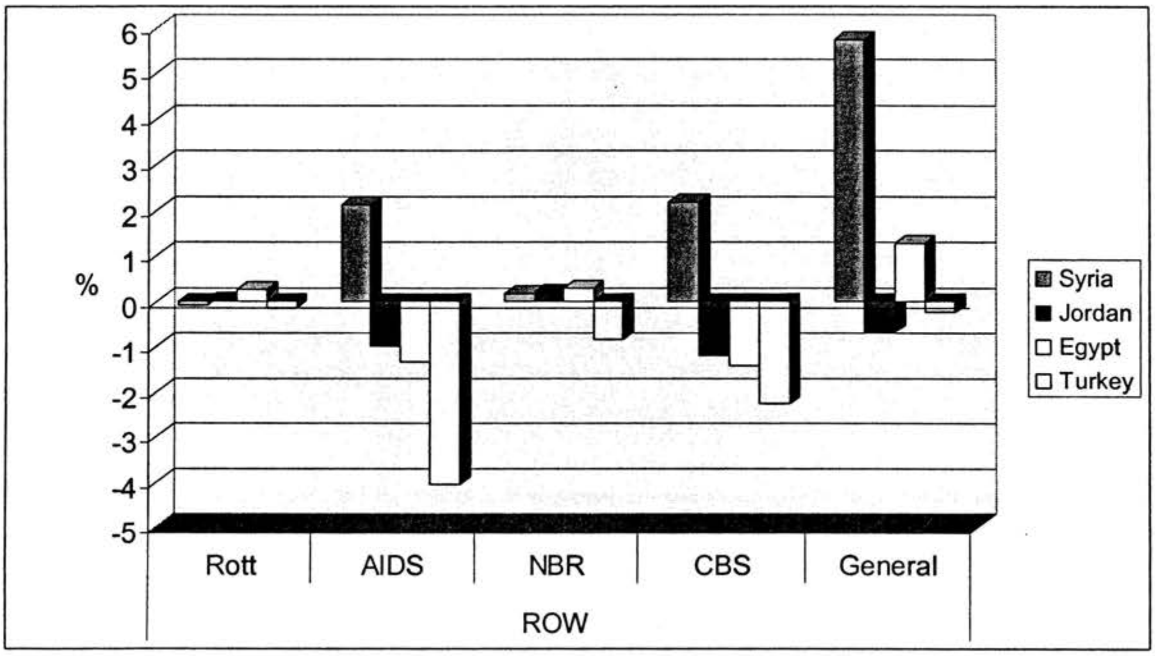


Figure 22. Percentage Change in Quantity Demanded Resulting from a 1% Increase in Expenditures on Imported Onions: Restricted Model.

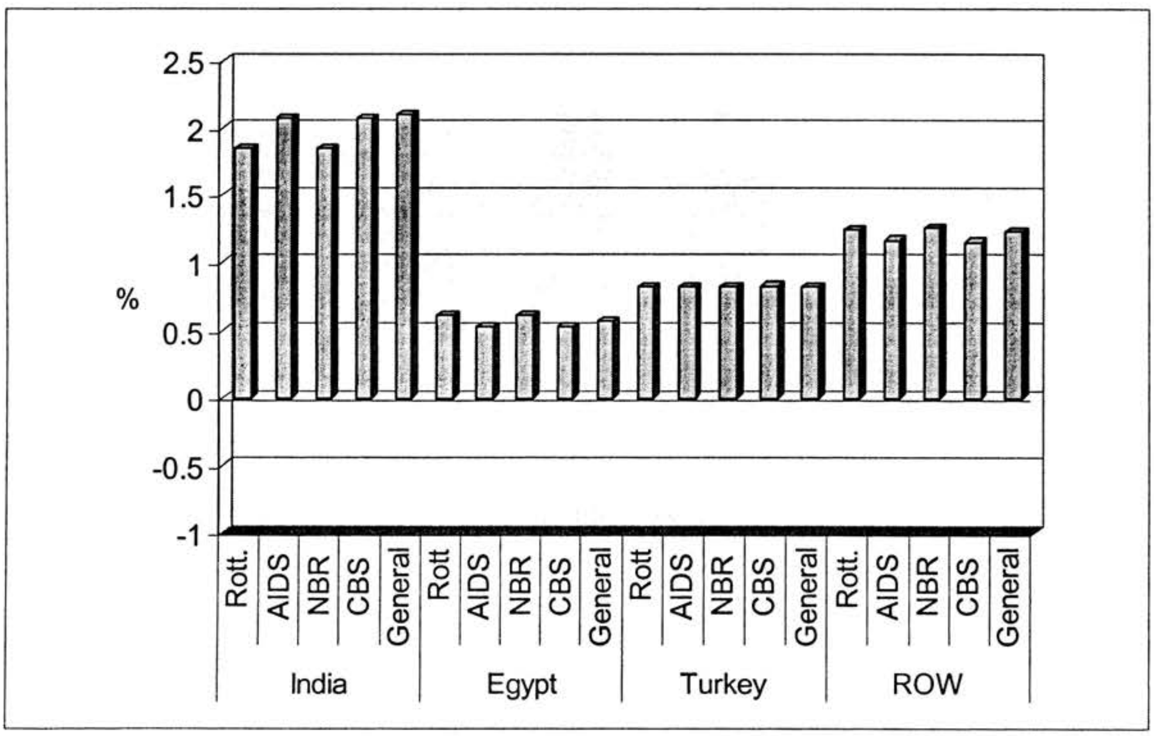


Figure 23. Percentage Change in Quantity of Imported Onions Resulting from a 1% Increase in Price of Onions: Restricted Model.

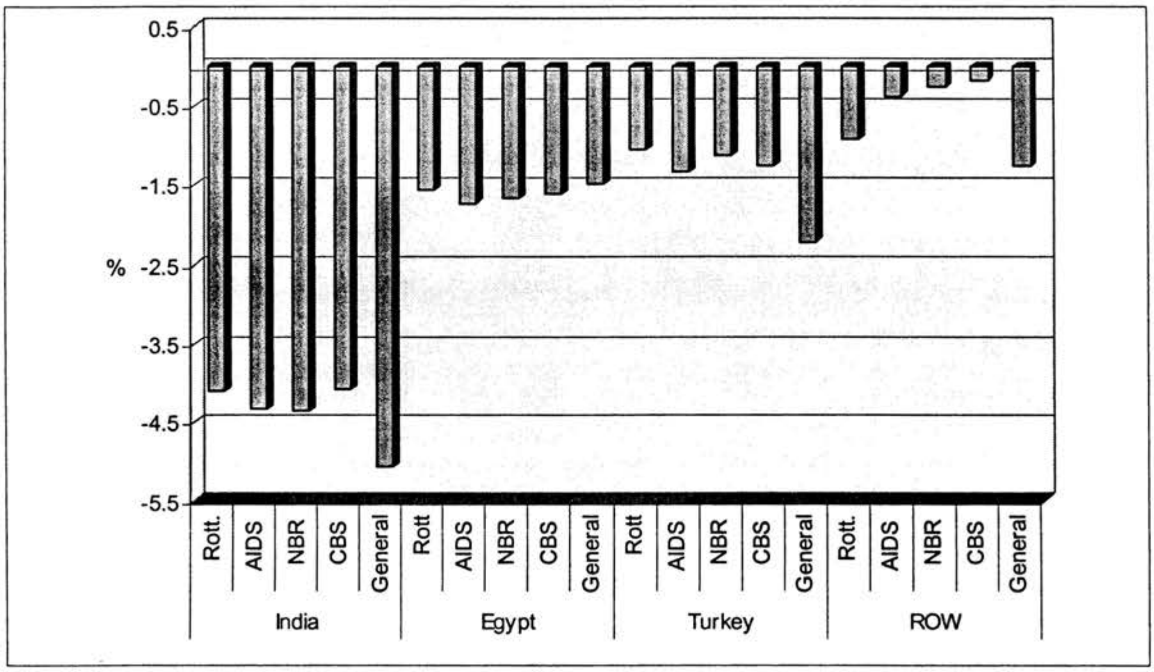


Figure 24. Percentage Change in Quantity of Indian Onions Demanded Resulting from a 1% Increase in Price of Onions from Other Sources: Restricted Model.

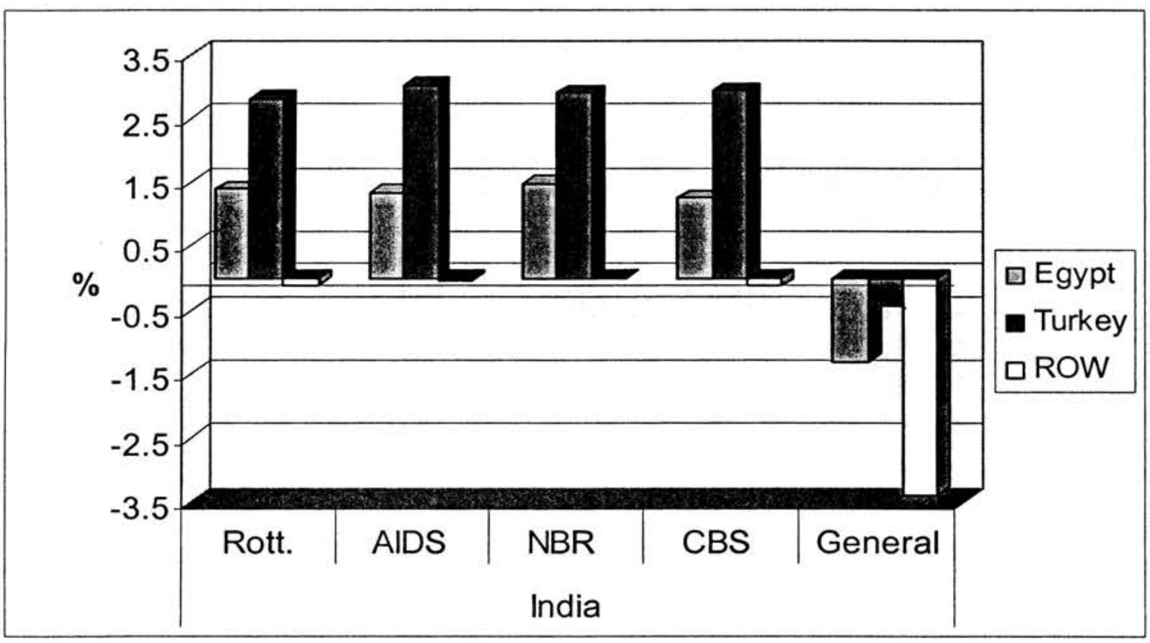


Figure 25. Percentage Change in Quantity of Egyptian Onions Demanded Resulting from a 1% Increase in Price of Onions from Other Sources: Restricted Model.

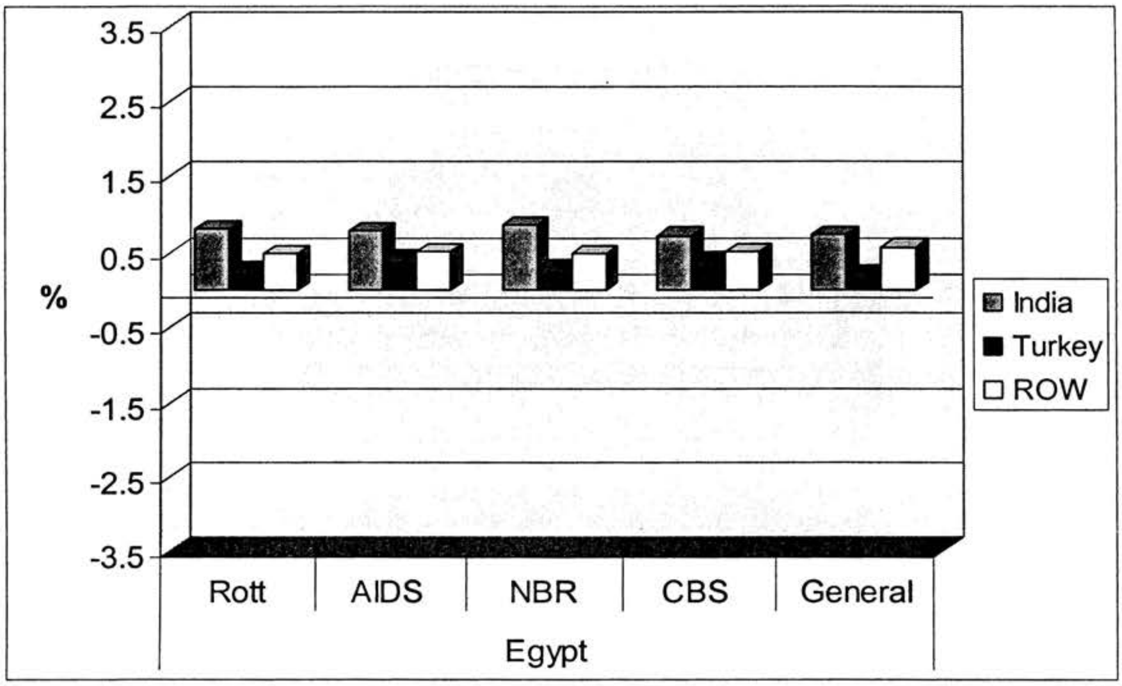


Figure 26. Percentage Change in Quantity of Turkish Onions Demanded Resulting from a 1% Increase in Price of Onions from Other Sources: Restricted Model.

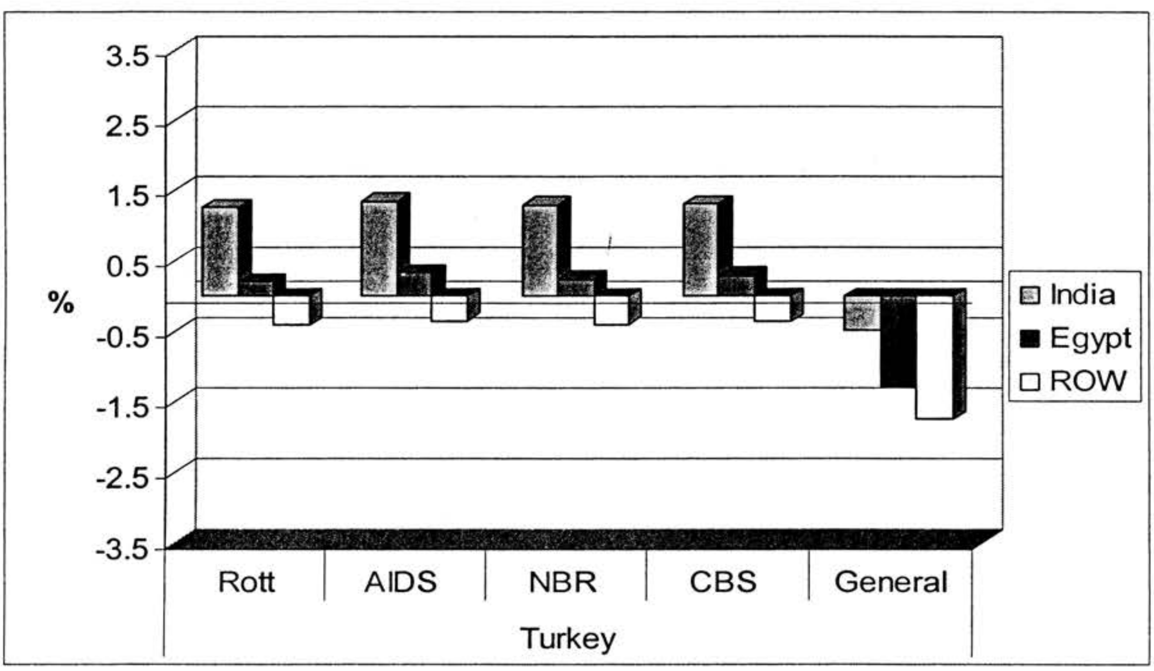
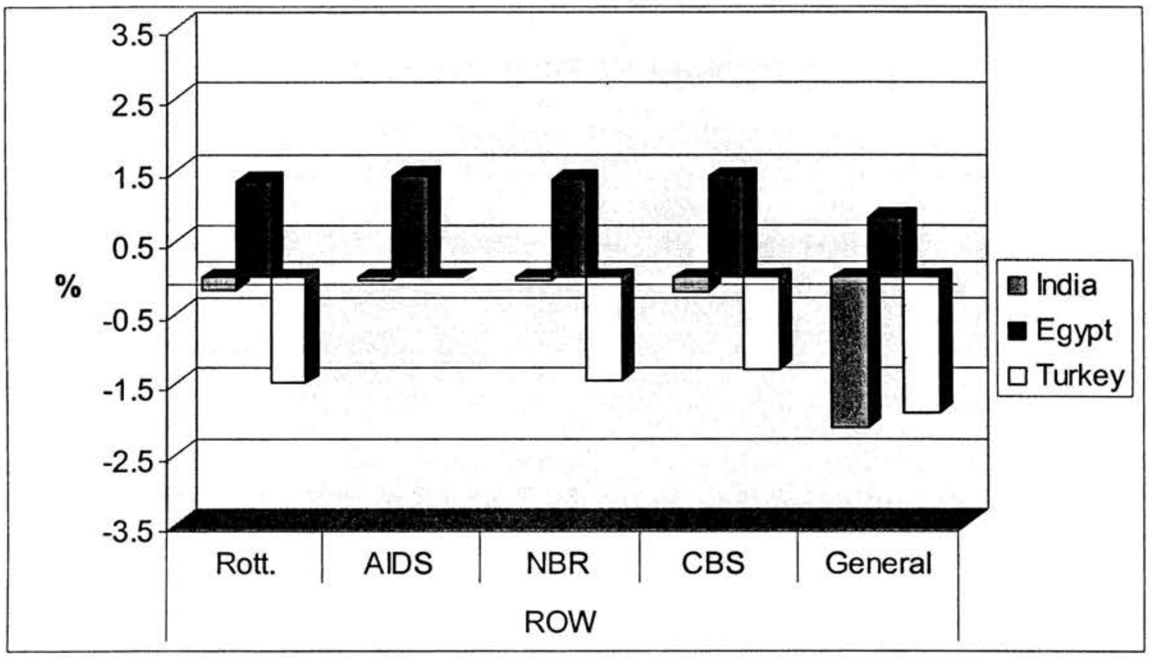


Figure 27. Percentage Change in Quantity of ROW Onions Demanded Resulting a from 1% Increase in Price of Onions from Other Sources: Restricted Model.



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