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# Export Subsidies in an Imperfectly Competitive Market When Market Share Matters: The Case of International Wheat Trade

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EXPORT SUBSIDIES IN AN IMPERFECTLY COMPETITIVE MARKET

WHEN MARKET SHARE MATTERS:

THE CASE OF INTERNATIONAL WHEAT TRADE

A Thesis

Submitted to the Faculty

of

Purdue University

by

Panu Kyösti Samuli Kallio

In Partial Fulfillment of the

Requirements for the Degree

of

Doctor of Philosophy

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To my wife Anu, and to my children Elisa and Tuomas

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Helsinki, January 1998 Panu Kallio

AGRICULTURAL ECONOMICS RESEARCH INSTITUTE
P.O.Box 3, FIN-00411 HELSINKI, Finland
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# EXPORT SUBSIDIES IN AN IMPERFECTLY COMPETITIVE MARKET WHEN MARKET SHARE MATTERS: THE CASE OF INTERNATIONAL WHEAT TRADE

PANU K.S. KALLIO

**Abstract.** A dynamic, game theoretic model with switching costs provides better understanding of motives that keep export subsidies a part of exporters' agricultural policies. Switching costs include factors, such as transactions costs and political considerations, that affect an importer's purchasing decisions. Effects of these costs are dynamic in nature, because switching costs vary with the level of earlier purchases.

Behaviors of exporting countries and firms are not driven solely by maximization of current welfare and profits, but also by the desire to increase current market share, which could improve future welfare and profits. In our multi-period framework, exporting countries face a tradeoff between exploiting current market share with higher prices and lower export subsidies, or competing for larger market shares with lower prices and larger subsidies.

In wheat export competition to Morocco, the EU and U.S. are noncooperatively behaving "super-powers" whose actions influence each other's agricultural policies and world prices. Subsidized exports of EU and U.S. wheat are sold abroad by large exporting firms who may also have market power.

Econometric estimates of import demand functions suggest switching costs exist in the Moroccan market, and switching costs from U.S. wheat are larger than costs from EU wheat. Exporting firms charge lower prices and higher export subsidies are awarded by governments when switching costs are present. This suggests that costs of export promotion programs may be higher than is often expected.

Investigation of alternative institutional arrangements (game structures) showed that unilateral elimination of export subsidies is the worst scenario for the country eliminating subsidies. Improvement of U.S. welfare in the free trade case explained its initial willingness to eliminate export subsidies under GATT. MacSharry CAP reform helped make GATT upper bounds for EU export subsidies more acceptable, consistent with the notion that it was an important element in reaching GATT agreement.

Finally, results show that, while it is important for exporting countries to prevent formation of a firm cartel, some degree of firm level market power is welfare improving for exporters. Results also suggest that order of play has important implications for players' market power and so, strategic behavior.

**Index words:** Trade policy, Export subsidies, Switching costs, Imperfect competition, Dynamic oligopoly, Wheat

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# CHAPTER I

# INTRODUCTION

On April 15, 1994, 111 countries meeting in Morocco signed the Final Act of the Uruguay Round GATT (General Agreement on Tariffs and Trade) Agreement. At the same time, GATT as an institution was replaced by the World Trade Organization (WTO). Agriculture for the first time since GATT's inception in 1947 played a central role in the negotiations. The ability of countries to define and control export subsidies in agriculture was one of the main issues under discussion in these negotiations. The Agreement on Agriculture, which was part of the Final Act document, attempts for the first time to ban new export subsidies. However, existing subsidies are allowed to continue subject to agreed reductions. Even after these reductions, export subsidies will remain an important part of international trade for certain agricultural products, especially wheat, which were previously heavily subsidized. This situation persists despite the substantial amount of agricultural trade policy research that has been conducted over the last twenty-five years (e.g. Abbott 1985, Anania et al. 1992) showing losses in national and world income due to export subsidies. Therefore, a better understanding of the motives that keep export subsidies as a part of an exporting country's agricultural policy is needed.

Another concern of this research is the fact that governments of exporting countries, as well as exporting firms, often seem to be interested in their market shares in world commodity markets in addition to their short run welfare and profits. For example, Gehlhar and Vollrath (1997) state that the U.S. Department of Agriculture commonly uses market share as a measure of export performance. Also, one of the reasons for the introduction of the Export Enhancement Program (EEP) by the U.S. was to recapture a larger share of the international agricultural commodity market (Hillberg 1988). This emphasis on market share probably has effects on adopted export policies in international agricultural trade, but so far agricultural trade research has not been able to explain why market share matters.

The purpose of this dissertation is to shed further light on export promotion behavior of major exporting countries in international agricultural markets. An improved understanding of the major players' behaviors in international markets can have positive implications for future multinational trade negotiations as well as for individual trading countries. On the one hand, the better the motives for using export promotion policies are understood, the better starting point is provided for future GATT negotiations. On the other hand, this improved understanding can help major exporting countries identify implications that their own behaviors in international agricultural trade have on each other's behaviors.

## 1.1. Imperfect Competition in Agricultural Trade

International agricultural markets often exhibit conditions of imperfect competition, with interdependence among countries and firms trading their products (McCalla and Josling 1981). In many cases the trade of commodities is dominated by a few large countries or regional blocs, who can affect world prices. Furthermore, institutions exist through which market power in trade may be exercised: the Export Enhancement Program in the United States and export restitutions of the European Union, for example. This market power is found more often in public agencies than in private firms, although in markets such as the international wheat market large exporting firms also may have some market power (Patterson and Abbott 1994, McNally 1993).

By looking at the underlying criteria used to fix export subsidies of large exporting countries like the U.S. and EU, it is clear that these countries carefully follow each other's behavior in the market when setting their subsidy levels (CAP Monitor 1996, Hillberg 1988). Understanding of export policy behavior, therefore, requires methods that can capture strategic interaction between these market agents. In addition, whenever exporting firms have market power, they can influence price either through the level of price they negotiate in the importing country or through the level of export subsidy they get from their government.

Agricultural trade research has for a long time recognized the importance of imperfect competition. McCalla in 1966 first argued that wheat trade should be explained as a duopoly involving the United States and Canada. Thereafter, several journal articles have been published in this area. The most commonly utilized method has been the static conjectural variations approach (e.g. Kolstad and Burris 1986, Paarlberg and Abbott 1986, 1987, Thursby and Thursby 1990). This approach, however, has been criticized as an ad hoc way to model dynamic features in a static framework (e.g. Tirole 1988, Helpman and Krugman 1989). Some other recent studies have applied explicit game-theoretic methods in order to capture strategic interactions between players in the market, but the majority of these studies have also used static models in their analysis (e.g. Hillberg 1988, Johnson et al. 1993, Kennedy et al. 1996, Abbott and Kallio 1996), even though in practice firms and governments are interacting repeatedly. So far, a very limited number of dynamic, game theoretic agricultural trade studies exist (e.g. Karp and McCalla 1983, McNally 1993).

Another important matter that should be recognized when analyzing trade policy behavior is politics. Agricultural trade policy complements domestic agricultural policy in its income redistributional goals. It is apparent from casual observation of agricultural trade policy that governments respond to the concerns of favored domestic groups, especially agricultural producers (and producers generally). As Krugman (1997) states, it is a fact of life that trade policy tends to place a much higher weight on producers than on consumers. The political economy literature emphasizes these distributional considerations, viewing trade policy as a device for income transfers to preferred interest groups in society (Helpman 1995).

Empirical work in this area specific to agricultural trade has been done by Sarris and Freebairn (1983), Paarlberg and Abbott (1986), Johnson et al. (1993), Kennedy et al. (1996) among others. All of these studies used the political preference function (also called criterion function) approach suggested by Rausser et al. (1982). In this approach the policymaker's objective function is given as a weighted sum of domestic special interest groups' welfares. Note that there is an overlap with imperfect competition studies mentioned earlier. When strong special interest groups exist in the market, they can, by lobbying, make the government utilize its market power such that it favors these special interest groups. The existence of export subsidies, for example, illustrates the producer bias in agricultural policy setting.

## 1.2. Importing Country Behavior

Another important aspect of international agricultural trade is the behavior of an importing country. Several factors affect an importing country's purchasing decisions. The price of the product is an obvious and often the most important factor. However, in reality it is very seldom observed that an importing country purchases all of its imports from the least expensive supplier. Another factor affecting the importing country's decision to buy is the quality of the good. For example, qualitative characteristics of EU wheat and U.S. wheat are not the same, and this difference is argued to be one of the factors affecting trade flows of these two goods in the world market (Ackerman 1993).

One general group of factors that may also influence an importing country's purchasing decisions is called *switching costs* ("brand loyalty"). Wilson et al. (1987), for example, found that some degree of brand loyalty exists in international wheat markets. Blandford (1988) as well as To (1994) state that these costs, borne by the importing country, of switching from one exporter to another might exist for many reasons. An importer incurs costs negotiating a contract or agreement with a supplier, and these transaction costs with a new exporter may be higher than with an existing exporter. Traditions of language and custom may limit an importing country's willingness to switch between suppliers, for example. Another category is learning costs. There is more risk involved when buying from a new, unfamiliar source than when buying from an existing supplier. There also might exist political costs of switching between exporters. One would expect products supplied by political allies to be viewed differently from others. In addition, guaranteed credit programs and government relationships can induce switching costs. Under U.S. credit guarantee programs, for example, an importing country can only use the proceeds of a guaranteed loan to purchase U.S. products.

In the group of traditional agricultural trade models, Armington-type models have been developed to account for features that differentiate commodities according to country of origin. This approach was first applied in agricultural trade modeling by Grennes et al. (1977). Armington-type models exhibit much smoother changes in trade shares than the traditional spatial equilibrium model, and account more adequately for observed trade flows. However, one problem with Armington-type trade models is that they are static models in which differentiation between wheat suppliers is done using a constant elasticity of substitution parameter. Effects of switching costs, on the other hand, are dynamic in nature, because switching costs that an importing country faces now are created by earlier purchases of the good. In order to capture the effects of switching costs a dynamic modeling framework is needed. However, as mentioned earlier, a very limited number of dynamic, game theoretic agricultural trade studies exist, and none have employed the switching cost approach.

## 1.3. Product Focus

This study focuses on international wheat trade, since wheat exports have been heavily subsidized and the market is highly concentrated. For the years 1972/73 through 1995/96, five exporters – the U.S., EU, Canada, Australia, Argentina – supplied an average of 92.2 percent of world wheat exports (International Grain Council). Although the roles of Argentina, Australia, and Canada are important parts of the international wheat market story, the emphasis of this research is on export promotion behavior of European Union and United States and how they relate to each other. After all, the noncooperative strategic behavior of these two exporters is one of the main reasons why export subsidies still (can) exist in international agricultural trade after the GATT Uruguay Round Agreement (Abbott and Kallio 1996). They were the main combatants over agricultural export subsidies in GATT negotiations. The fact that it was only after long bilateral discussions between the U.S. and the EC that an agreement in the export subsidy reductions was reached illustrates well their importance in international agricultural trade (OECD 1995).

The European Union and the United States can be described as two noncooperatively behaving "super-powers" in the international wheat market, whose actions in the market have an influence on each other's agricultural policies as well as on world market prices. The most significant strategic variable for these countries has been an export subsidy. In the European Union, export restitutions (export subsidies) are used to ensure that EU wheat is competitive on world markets. Export restitutions are intended to bridge the gap between the usually higher EU intervention price that wheat traders could receive on the EU market and the lower price they would obtain by exporting to the world market (CAP Monitor 1996). Similarly, in 1985 the Export Enhancement Program was established to make U.S. agricultural exports more competitive and to counterbalance "unfair trade practice of the European Community" (Hillberg 1988). Wheat has been one of the most heavily subsidized exports of both the EU and U.S. since the introduction of the EEP.

Subsidized exports of EU and U.S. wheat are sold abroad by large exporting firms, and some evidence has been provided that firm level price competition is oligopolistic (imperfect) in nature (Patterson and Abbott 1994, McNally 1993).

The best markets in which to observe consequences of the strategic interaction between the EU and U.S. are the North African importers (Egypt, Algeria, Morocco, and Tunisia), traditional buyers of French wheat and flour. This is because these markets have been the largest targets of the EEP. In the case study of this research we concentrate on the Moroccan wheat import market which has been controlled almost exclusively by the EU and U.S. (from 1980/81 through 1993/94 over 95 percent of Moroccan wheat imports have been either from the U.S. or EU).

Wheat is a heterogeneous product, since importing countries do not view wheat from different sources as qualitatively identical products. For example, Moroccan buyers find EU wheat to have lower protein content and higher moisture content than U.S. wheat. These qualitative differences have an impact on how much wheat importing countries decide to purchase from each source (Ackerman 1993). Furthermore, support exists for the fact that importers in the international wheat market may experience some costs of switching from one supplier to another. Wilson et al. (1987), for example, used a Markov model to study import loyalty in international wheat markets. They found that brand loyalty in international wheat markets exists, and they also stated that the U.S. as wheat exporter seems to enjoy greater brand loyalty than the EEC.

## 1.4. Methodology and Objectives

The characteristics of international wheat market suggest that in order to analyze behaviors of major players in the market, such as the EU Commission, the U.S. government and their exporting firms, strategic interaction between them needs to be recognized. In addition, when importing countries experience costs of switching between wheat suppliers, these costs need to be taken into account in the modeling framework. One purpose of this dissertation is to develop a dynamic, game theoretic model of international wheat trade that incorporates strategic interaction among players who exercise market power, and simultaneously is able to capture impacts that switching costs have on players' strategies. This is accomplished in two stages. First, a theoretic two-period model of oligopolistic competition with differentiated products and switching costs is constructed. The notion of switching costs draws upon consumer switching cost theory which has been developed to deal with fact that, in many markets, consumers who have previously purchased from one firm have costs of switching to a competitor's product, even when the two firms' products are functionally identical (Klemperer 1995).

The two-period model is developed such that the importing country has no switching costs in the first period but in the second period switching costs are developed as a result of its first-period purchases. Therefore, exporting countries and firms have some additional market power in the second (final) period, because the costs of changing suppliers partially force the importing country to continue buying products it purchased in the first period. In each period, exporting country governments simultaneously choose their export subsidies (taxes if negative) to maximize domestic welfare. After that, firms in both exporting countries simultaneously set their prices to maximize profits. The model is explained in detail to highlight the theoretical effects that the introduction of switching cost has on the behavior of exporting countries (both firms and governments).

This modeling approach with switching costs was found to be useful because it provides insight into the importance attached to market shares by exporting countries. If an exporting country is able to increase its market share, this creates additional costs for the importing country to switch away from that exporting country's wheat in the future. Each exporting country and each exporting firm realize this. Therefore, their behaviors are not just driven by maximization of current period welfare (exporting country) and profits (exporting firm), but also by the desire to increase current market share which could improve future welfare of the exporting country and future profits of the exporting firm. Hence, the notion of switching costs in the market provides an intuitive explanation why exporting countries and firms are often concerned with market share in addition to short run welfare and profits.

Since one of the goals in this research is to empirically analyze the effects of policy shocks or other shocks in the economic environment of international wheat trade, two-period models are not the most appropriate to be used. In the real world we observe more than two periods, and any given period is not really well classified as either a first or a second period, but as some intermediate period which is not without switching costs. Therefore, the second stage of the modeling process extends the two-period model into a more general empirical multi-period model of competition in a market with switching costs. This empirical model is then used to examine several scenarios in order to answer our research questions.

In a multi-period framework with switching costs exporting countries in each period face a tradeoff between "the first-period action" and "the second-period action" of the two-period model. That is, they can either exploit their current market shares with higher prices and lower export subsidies ("the second-period action") or compete for larger market shares with lower prices and larger subsidies ("the first-period action"). In the switching costs literature, Beggs and Klemperer (1992) state that we should expect firms' incentives to exploit current market share to dominate their incentives to increase market share that could be exploited later, and so lead to higher prices in markets with switching costs than in markets without switching costs.

This research will answer two questions that follow from Beggs and Klemperer:

- Do exporting firms charge higher prices and collect larger rents when switching costs exist in international wheat trade?
- Is the need for export subsidies smaller when switching costs exist in the international wheat market?

Abbott et al. (1987) found that a target export subsidy program, like the EEP, can be welfare improving because it allows an exporting country to price discriminate. By subsidizing relatively elastic markets, the exporting country is in effect taxing countries with relatively less elastic excess demand schedules. Switching costs make repeat-purchaser's excess demand more inelastic. This means that heavier subsidization may be required by an exporting country to increase its market share in a market with switching costs.

The empirical model will also provide answers to research questions that concern the use of the Export Enhancement Program in a market where switching costs exist:

- Do switching costs make the EEP more costly than without consideration of these costs?
- If switching costs make a targeted subsidy program's costs higher, does the unilateral termination of the EEP in a market with switching costs then become a more attractive export policy choice for the U.S. government than in a market without switching costs?

## 1.5. Organization of the Study

This dissertation consists of seven chapters. The next chapter provides background information on the institutional settings of the international wheat market as well as evidence on strategic interaction between market participants, in particular the EU and U.S. Chapter III surveys literature relevant to the analysis of world wheat market. The chapter begins with a critical review of the traditional agricultural trade modeling literature. The chapter then reviews empirical game-theoretic modeling techniques and their use in agricultural trade modeling, the political economy literature and switching cost theory.

Chapter IV first presents a theoretical two-period international trade model with switching costs. Then the chapter extends the two-period model into a more general multiperiod model with switching costs. The procedure for solving the multiperiod model is provided. Thereafter, in Chapter V, econometric estimates of the parameters used to construct the empirical model, along with econometric methods employed, are presented.

Chapter VI provides empirical model solutions. First the chapter presents the base solution and validates the model results. Then it illustrates how the model can be used to analyze export policies of governments as well as price setting behavior of exporting firms when strategic interaction among players and switching costs between goods in the market are present. To accomplish this task, several different scenarios are examined. Finally, Chapter VII summarizes the conclusions from this research and makes suggestions for future research.

# CHAPTER II

# THE INTERNATIONAL WHEAT MARKET AND EXPORT POLICIES

The purpose of this chapter is to describe the institutional setting for international wheat trade. First, developments of wheat-specific export policies in the European Community and United States from 1980 onward are examined. Since we will concentrate on Morocco as a key importing country, the third section highlights some facts regarding wheat imports by Morocco. Then the effects of the GATT Uruguay Round Agreement on export policies of the EU and U.S. are described. The final section provides evidence on strategic interaction between market participants, in particular the European Union and United States, in the international wheat market.

## 2.1. Export Policy of the European Union

The European Union (EU) is an economic union of fifteen countries (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom)[1]. The centerpiece of the European Union's grain market policy is the Common Agricultural Policy (CAP) which is based on three fundamental principles. First, the Community functions as a single market for agricultural commodities. Given the history of agricultural protectionism in the original member countries, this implied the replacement of national price support policies with a common price support system. Second, preference is always given to domestic producers of member countries over foreign competitors. This requires the use of measures, such as duties and levies, to keep the price of imported grain above domestically produced grain and EC prices above world prices. The third principle states that European Community members jointly finance costs of the CAP. This led to the creation of the European Agricultural Guidance and Guarantee Fund (EAGGF) to administer EC's agricultural expenditures. These principles

[1] On November 1, 1993, the European Union (EU) name came into being following the Maastricht Treaty. This incorporated twelve member countries of the former European Communities (EC) consisting (under the treaty of Rome) of the European Economic Community (EEC), the European Coal and Steel Community (ECSC) and the European Atomic Energy Community. As the plural form was confusing, reference was often made to "The Community". Since January 1, 1995 Austria, Finland, and Sweden have joined the EU. (Tracy 1996).

The terminology was further confused by the fact that the Maastricht Treaty renamed the European Economic Community the European Community, which continues to exist together with ECSC and Euratom. Here both expressions EC and EU have been used, depending on the context. However, these terms should be regarded as practically interchangeable.

were developed after signing of the Treaty of Rome in 1957 (Blandford et al. 1993).

During the 1970's, a significant transition in wheat trade took place in the European Community. Before the 1970s the Community was a net importer in the international wheat market, but the production stimulation and consumption disincentives created by the CAP led to a rapid increase in production of wheat relative to its consumption (Paarlberg 1993). As Figure 2.1 shows, from crop year 1978/79 onward, the European Community has been a net exporter of wheat with increasing quantities exported (IGC). These increasing exports of wheat have created significant additional costs for the EC budget through export subsidy expenditures usually needed to export wheat abroad.

As indicated earlier, the EAGGF covers the costs of Common Agricultural Policy. Since its introduction, the CAP has accounted for the majority of all Community expenditures. Agricultural price supports have increased steadily and now represent approximately half of all Community expenses. Of these, cereal price supports usually account for 15-30 percent of total price support payments. As an example, the cereal price support expenditures for 1993 totaled over 6.5 billion ECUs, of which 49 percent were devoted to export refunds. Primarily, these expenses are funded by value added tax revenues collected by member states. Import tariffs also provide the European Union with financial resources. The growing cost of agricultural support and increase in commodity surpluses create substantial difficulties for the CAP (EU Commission 1996).

The costly price support system of the EU is based on five elements: target price, intervention price, threshold price, import levy and export restitution. The target price, the highest of three prices, is the one which producers should receive for their products at the farm-gate. However, this is only true when the

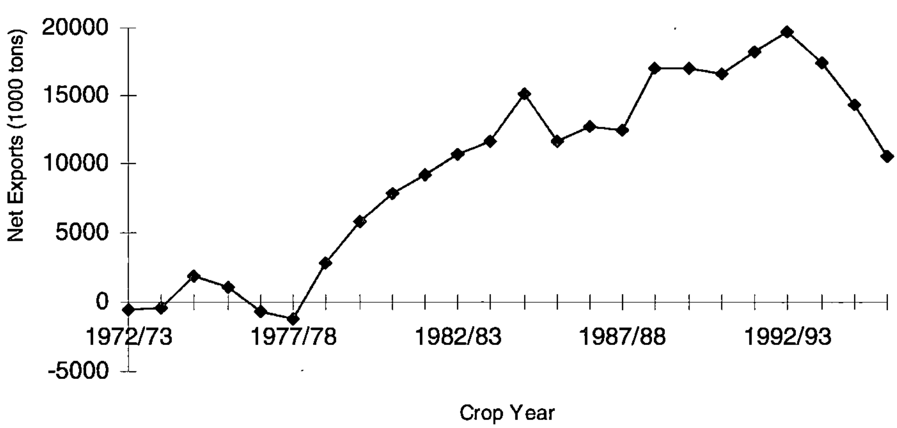


*Figure 2.1. Net Exports of Wheat From the European Community.*

EU is a net importer. In the case where the EU grain market supplies are in excess of domestic requirements, market prices are always lower than target prices. Target prices differ geographically, but Duisburg in Germany, which is located in the main grain deficit area, is used as the basing point.

The intervention price is the minimum support price at which the Community will purchase grain from farmers if they cannot obtain a higher price on the open market. The basis for this price is Ormes in France (the main surplus area). There is a range between the target price and the intervention price within which internal market prices for domestically produced grains are expected to remain. Since the EU is a net exporter of grains, domestic market prices have remained well below the target price, approximately around the intervention price.

The minimum price for importing grain into the EU is the threshold price. It is calculated by subtracting the transport costs for shipping grain between the port and Duisburg from the target price. To ensure that the threshold price is the minimum import price the difference between the threshold price and the border price (e.g., c.i.f. Rotterdam[2]) is used as the import levy. The introduction of the new Uruguay Round GATT rules in July 1, 1995 revised this import regulation. The function of the threshold price has been assumed by the newly created "155 percent intervention price"[3]. The difference between this and the c.i.f. Rotterdam price is no longer the import levy but the "import tariff". With the abolition of the threshold price, the target price lost its purpose. The target price was used as the basis for the calculation of the threshold price. Since it is no longer needed for that purpose it was also abolished on July 1, 1995 (Toepfer 1995)[4].

To promote the marketing of surplus grain outside the Community, export restitutions (export subsidies) are used to ensure that EU wheat is competitive on world markets. Export refunds are intended to bridge the gap between the usually higher EU intervention price that wheat traders could receive on the European Union market and the lower price they would obtain by exporting to the world market. In addition to this price difference, the amount of the refund also depends on the destination. In exceptional circumstances, when prices outside the European Union are above those inside, export levies may be imposed.[5] Figure 2.2 illustrates the relationships between the five EU price support elements.

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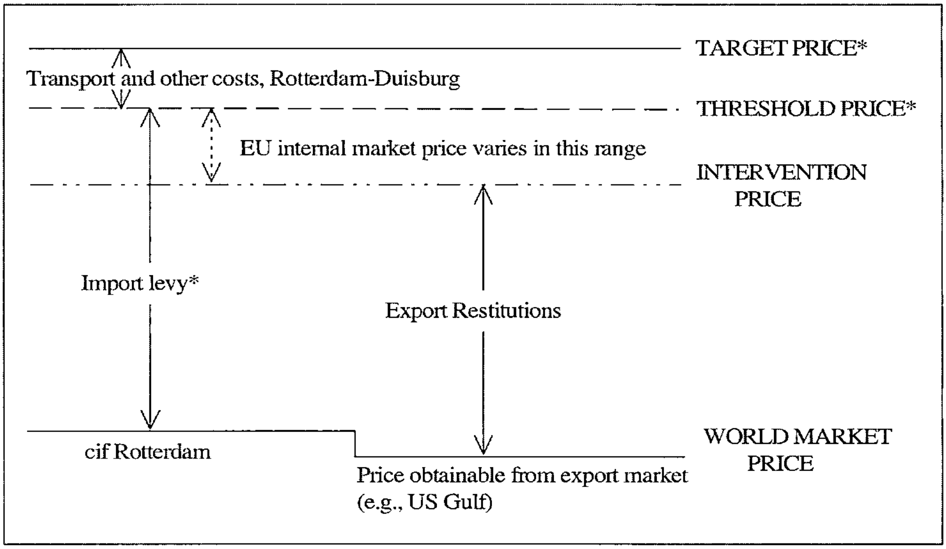
[2] c.i.f. is the abbreviation for costs, insurance, and freight. Prices paid by an importer at the border of an importing country are called c.i.f. prices.

[3] "155 percent intervention price" means that duty-paid import price of grain may not exceed the EU intervention price increased by 55 percent.

[4] The effects of Uruguay Round GATT agreement on export policies are discussed in separate section of this chapter.

[5] These exceptional circumstances actually occurred during the time period of December 1995 to March 1996, when export taxes were imposed on wheat exports (IGC 1996).




*Under new GATT rules the target price does not exist, the threshold price is replaced by "155 % intervention price", and import levy is replaced by "import tariff".

*Figure 2.2. The EU System of Grain Price Support.*

Since the emphasis of this research is on export subsidies, we explore here more closely the process of awarding export refunds. Refunds are determined weekly by the Cereals Management Committee (CMC) when it adjudicates tenders for refunds and fixes other non-tendered refunds for the following week (CAP Monitor 1996)[6].

The procedure for open market tenders is as follows. Exporters submit their sealed bids to authorities in a member country, who then send them to the Cereals Management Committee. The exporter's bid must contain information on the desired export volume and per unit refund. The Management Committee at its weekly meeting decides whether to fix a maximum refund on the basis of the bids submitted. If a maximum refund is fixed then a contract is awarded to any exporter who has submitted a bid equal to or less than the maximum refund. After the contracts are awarded, successful exporters are required to apply for an export license for the quantity awarded. The licenses are normally valid for the month when the tender was originally submitted and for four months thereafter. Normally, these export licenses are transferable from the successful tenderer to another party within the EC and a market for them exists (CAP Monitor 1996).

[6] Three types of tender are in use in trade – open market tenders for export refunds, tenders for the export of intervention stocks and food aid tenders. The open market tenders are most common.

Since allowing export refunds to be fixed by tenders can reduce EAGGF expenditure, tenders are widely used at present. Tenders can also be used to establish export levies, if these are in force (CAP Monitor 1996).

When assessing the level of the maximum refund to be granted at the open market export tender, it is evident that the European Union follows carefully the strategic behavior of the United States in international wheat trade. In particular, the price for US Soft Red Winter wheat, fob Gulf, is most commonly used as an indicative price that the Community is competing against in the world wheat market. The EU Commission also decides on an indicative EU export fob price (before the refund), which would usually be the fob price for French and/ or UK wheat from a major export port. The maximum export subsidy awarded will be that which equates most closely the EU net export price with the world price (US Gulf price) (CAP Monitor 1996).

### 2.1.1. The 1992 CAP Reform

In May 1992 the agricultural ministers of the twelve EC member states agreed on a completely new regime for the EC grain market – popularly known as the MacSharry Reform (named after the Commissioner then responsible for agriculture). In view of 1) the steadily growing surplus of grain in the Community of around 40 to 45 million tons, 2) the stagnating demand in both the export and domestic markets, 3) reduced producer prices (without compensation), 4) limited resources to finance this policy, and 4) aggravating conflicts with other grain exporting countries, there existed fruitful ground for adopting the reform measures now in force (Toepfer 1995).

The primary goal of controlling the quantities produced is to be achieved by a combination of price cuts, area set-aside, and more extensive production methods. The price cuts are also intended to make grain more competitive against imported feed stuffs and to lead to higher grain consumption in the EU (Toepfer 1995).

Farm incomes in the new system depend increasingly on direct income transfers (compensatory payments). This is because during the three year transition period (1993/94-1995/96) support prices for grains were cut by approximately 30 percent (almost 20 % in 1993/94 and not quite 8 % per year in 1994/95 and 1995/96). Average farms, to a large extent, are compensated for these drastic price cuts (Toepfer 1995). Producers who set aside at least 15 percent of their arable land are eligible to receive compensation.

From the export policy perspective it is important to notice that, due to the MacSharry Reform, the same amount of wheat can be now exported with considerably smaller export refund costs to the EU budget. However, no reduction in total support payments on cereal production has occurred. Instead, an enormous increase in those payments has occurred. These facts can be seen by comparing 1993 and 1995 EAGGF expenditures on cereal production. Export refund expenditures in 1995 were only 29 percent of 1993 export refund expenditures (907 million ECU versus 3153 million ECU) although total support on cereal production was more than twice as large as two years earlier (14574 million ECU versus 6459 million ECU). The major share of cereal support in 1995 was paid through compensatory payments (10744 mill ECU) (EU Commission 1996).

## 2.2. Export Policy of United States

In the United States price supports for grains were first introduced by the 1933 Agricultural Adjustment Act to alleviate hardship arising from the Great Depression. Until 1996 the United States used a mix of acreage reduction programs, loan rate and target price protection, and storage programs, together with export subsidies to support farm prices and incomes.

A key element in U.S. government program for grains is a support price called the loan rate. It is a price per bushel set annually through the political process. The loan rate is intended to operate as a floor price for grains, and to offer farmers an alternative to immediate sale of their grain at harvest. The farmers that participate in government programs have the option to place some or all of their production under loan with a public corporation called the Commodity Credit Corporation (CCC). Farmers receive a payment equal to the loan rate for each unit of production pledged as collateral to the CCC. At any time during the next 11 months the farmer has the option of repaying the loan (plus interest and storage charges) and selling the stored grain on the open market. Alternatively, a farmer can default on his loan and the commodity becomes the property of the CCC. Forfeiture of grain to the government is most likely to happen on a large scale when market prices are below the loan rate (plus interest and storage charges) (Blandford et al. 1993), leading also to rapid growth in government stocks.

Other elements of the U.S. price and income support system until 1996 were direct income payments, target price, acreage reduction, and export subsidy. Direct income payments, called deficiency payments, were made to participating grain producers based on the difference between a target price and the higher of either the market price or the loan rate (Blandford et al. 1993). The target price, which was generally above both the market price and the loan rate, was set through a political process at the beginning of each Farm Bill and it applied five years into the future.

To be eligible for price and income supports, producers were required to set aside or take out of production a minimum proportion of their arable land. The purpose of this acreage reduction program was to raise the market price by reducing supply, and to limit the amount placed under loan and in CCC stocks.

The 1996 Farm Bill was signed into law in April 1996, providing new farm sector law for 1996-2002. The previous income support system, based on established target prices and deficiency payments, was replaced by a series of annual payments (production flexibility contract payments) whose levels are unrelated to current market prices or production levels. Most acreage use restrictions from previous law were not continued. The mechanism of nonrecourse commodity loans was modified slightly. Minimum loan rates continue to be based on a moving average of past market prices, but maximum loan rates were also established equal to 1995 loan rates (Young and Westcott 1996).

Since the focus of this dissertation is on export subsidies, the remainder of this section explains the U.S. export subsidy program, the final element of the price support system, in greater detail.

### 2.2.1. The Export Enhancement Program

In the 1950s and 1960s export subsidies were used extensively by the United States. They were terminated in early 1970s when the large wheat purchases by the former Soviet Union (the "Great Grain Robbery") combined U.S. export subsidies with market failure at a time of world grain shortage[7].

Several factors contributed to the reintroduction of the export subsidy program in the mid-1980s. On the domestic side, the United States instituted the Agricultural and Food Act of 1981 which increased the target price and loan rate levels for wheat. In fact, loan rates exceeded market prices, increasing the incentive to sell to the CCC, and thus leading to large carryover stocks (Goldberg and Knetter 1995). On the international side, the early 1980s were plagued with global recession, which led to debt crises in many developing countries. Not only were there fewer resources to finance imports, but also the strong appreciation of the dollar eroded the competitiveness of U.S. wheat exports relative to foreign produced wheat. Last but not least, the extensive subsidization of wheat exports by the European Community meant that the EC was gaining wheat export market share while the United States was losing it, as can be seen from Figure 2.3.

All these domestic and international factors contributed to the substantial reduction in the U.S. world market share in the early 1980s. In 1981/82 the United States owned 49 percent of the world wheat market, but by 1985/86 its share of international wheat exports had fallen to 29 percent.

[7] The market failure was information failure in which the former Soviet Union secretly purchased a very large amount of wheat but in sufficiently small quantities from each exporting firm. Thus, the price was not increased with each sale as it would have in an efficient market featuring full information (Tweeten 1992).

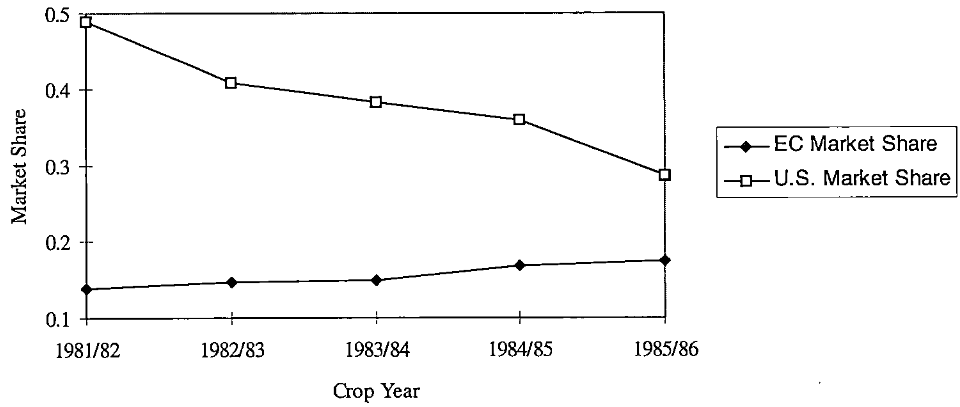



*Figure 2.3. EC and U.S. Market Share in the World Wheat Market Before Introduction of U.S. Export Subsidy Program.*

Against this background, the United States Food Security Act of 1985, which outlined the farm policy for crop years 1986-90, was enacted to reduce government stocks and improve the situation in the export markets through a series of measures. A reduction in the loan rates was designed to lower U.S. prices for wheat, making U.S. wheat more competitive in the export markets while reducing the growth in government stocks. To maintain farm income support, target prices were frozen at the 1985 level for crop year 1986/87 and slowly decreased afterwards (Goldberg and Knetter 1995).

In addition, the export subsidy program (Export Enhancement Program, EEP) was established to make U.S. exports more competitive. It was designed in such a way that it would simultaneously contribute to the reduction of government stocks. Under the original program, government-owned surplus commodities were paid as bonuses to exporters to allow them to lower the prices of U.S. agricultural products in specific markets. Wheat and wheat flour have received the largest share of subsidy dollars, accounting for 75 percent of the total export subsidy expenditures in 1994 (Federal Register 1995). Haley and Skully (1995) state that wheat has accounted for over 80 percent of the value of all EEP-assisted sales.

The Foreign Agricultural Service (FAS) of the USDA that administers the EEP program specified four criteria for evaluating sales under EEP (Hillberg 1988, Goldberg and Knetter 1995):

1) Additionality: Each EEP sale must increase agricultural exports above the level that would have occurred in the absence of the program.
2) Targeting: Export subsidies should be targeted to markets where the European Community heavily subsidizes. That is, the EEP is not a global export promotion program.

3) Cost effectiveness: Sales should result in a net gain to the overall economy.
4) Budget neutrality: The EEP must not cause budget outlays beyond what would have occurred in the absence of the program. At the beginning as an in-kind subsidy program the EEP served this purpose directly, since no cash payments were made to exporters and the government saved on the storage costs of the surplus commodities. In the later years, even though in-kind bonuses were replaced by cash payments, the EEP can be viewed as a substitute for domestic support payments, because by increasing export sales and thus supporting higher domestic wheat market prices, the program reduces the amount of deficiency payments to producers.

On November 27, 1989, the FAS reformulated the guidelines for the EEP in the Federal Register. The new guidelines emphasize the EEP's trade policy objectives. The first guideline requires that the EEP should have a potential to further the U.S. negotiating strategy in the GATT Uruguay Round by countering competitors' subsidies and other unfair trade practices. The second guideline requires FAS (EEP) to develop, maintain and expand markets for U.S. agricultural commodities. The third states that the EEP should not have more than minimal effects on nonsubsidizing competitors. The last guideline requires that the overall EEP program level and subsidies for individual EEP sales should be maintained at the minimum budget level necessary to achieve the EEP's trade policy and export expansion goals (Ackerman and Smith 1990).

Operationally, the EEP is a complex program that involves several steps. First, the FAS receives and reviews proposals on targeted countries and commodities from USDA officials, the American farming community, and foreign governments before selecting countries and commodities to target. If a proposal is approved, then it is announced as an initiative, specifying the targeted country and the maximum quantity to be exported under subsidy. After the initiative is announced, exporting firms negotiate with the targeted country to determine the quality, quantity, and price of wheat they will deliver. The conditional sales contract is then submitted as a bid to the FAS along with the firm's bid for EEP bonus (subsidy). If the price specified in the bid is less than the minimum acceptable price set by the FAS, the bid is rejected. If the price is higher, then FAS compares the bonus amount to the maximum acceptable bonus. If the exporter's bonus is too high, the bid is rejected[8]. If the price and bonus are accepted, the FAS compares its bonus amount to the bonus amounts of all acceptable bids received and awards the subsidies in ascending order of bonuses until the approved quantity is filled (Goldberg and Knetter 1995).

[8] However, a rejected bid can be revised and resubmitted the next business day.

Prior to November 1991, these bonuses were paid in the form of commodity certificates with value equal to the per-unit bonus times the quantity of wheat shipped under the contract. Exporters could exchange the certificates for an equivalent value of surplus commodities in government storage or sell them. Since November 1991, the commodity certificates have been replaced by cash subsidies (Haley and Skully 1995).

The EEP was originally arranged as a three year export promotion program in which $2 billion worth of surplus commodities were made available for exporters as bonuses. However, the Omnibus Trade and Competitiveness Act of 1988 raised the ceiling to $2.5 billion, and by the end of 1990 approximately $2.9 billion had been allocated to subsidize U.S. agricultural exports. The Food Agriculture Conservation and Trade Act in 1990 significantly expanded the budget of the EEP, setting a minimum of $500 million per year for 1991-95. An additional $1 billion became available for the period October 1993 to September 1995, since no GATT agreement was reached by September 1992 (McNally 1993).

As mentioned above, the EEP was designed as a targeted subsidization program to recapture market share that the United States claimed to have lost to the European Community through its continued export subsidies. Initially the EEP was targeted primarily to the northern Africa (to Morocco among others) in strategic response to subsidized EC wheat exports to those markets (McNally 1993). Figure 2.4 shows the development of EC and U.S. market share in the Moroccan wheat import market before and after the introduction of EEP. Considerable changes occurred in market shares right after the EEP was introduced. For a moment the U.S. was able to capture almost the whole market. However, EC quickly regained its market share during the subsidy war between the EC and the U.S. triggered by the introduction of the EEP.

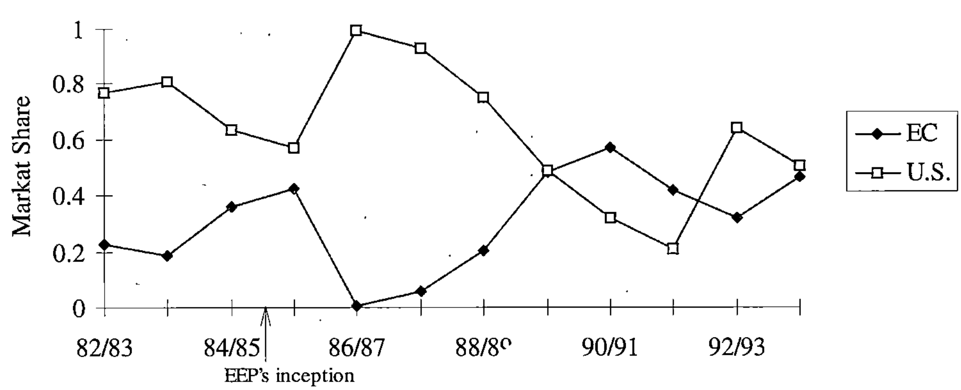



*Figure 2.4. EC and U.S. Market Share in Morocco.*

## 2.3. Importing Country Behavior: Morocco

Grains are an important food item in Morocco and represent a large share of household food expenditures: 25.3 % in 1970 and 23.6 % in 1985. Most wheat produced, and a major share of imported wheat, is used to make bread, a staple of the Moroccan diet. Morocco's per capita wheat consumption is about 150 kilograms per year. Wheat imports account for a large and increasing share. In 1992 for example, wheat imports by Morocco were 118.5 kilograms per capita (Kchit 1994). The development of total wheat imports to Morocco are illustrated in Figure 2.5 below.

Morocco generally imports only common milling wheat, although during drought years durum wheat is also imported. In some years small amounts of wheat are imported for feed use (Ackerman 1993). The major suppliers of wheat imports since 1979 have been the European Union and the United States (see Figure 2.4).

Both the EU and the U.S. subsidize their exports to Morocco through export restitutions and EEP bonuses, respectively. In addition, they both subsidize exports through export sales credit guarantees.

For U.S. wheat exports, the U.S. Department of Agriculture operates two export credit programs. Under the Export Credit Guarantee Program (GSM-102), USDA guarantees repayment of private credit extended to importers in specified countries and covers credit extended for up to three years. The Intermediate Export Credit Guarantee Program (GSM-103) covers private credit extended for more than three years and up to ten years.

Morocco used the GSM-102 program to assist its commercial purchases of U.S. wheat from 1981 through 1987. At the same time it became one of the major participants in the blended credit program in 1984 and 1985. This pro-

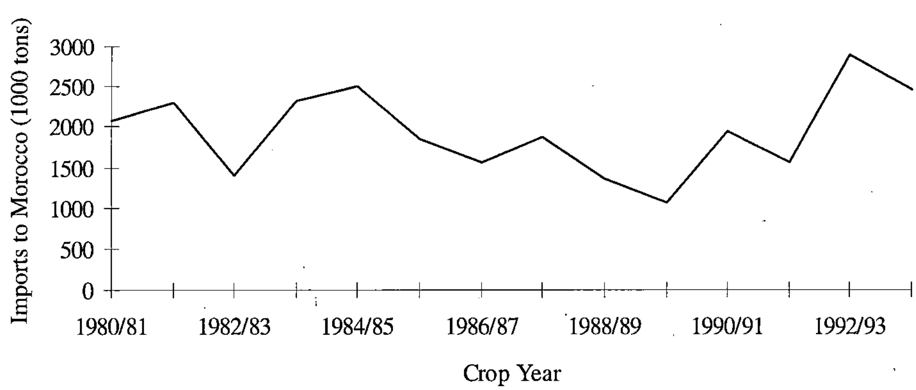



*Figure 2.5. Moroccan Wheat Imports.*

gram combined a zero-interest government loan with a credit guarantee. The blended credit program was suspended in 1985. In 1987, Morocco for the first time used the GSM-103 program to obtain 7-year loans to buy U.S. wheat. By 1988, all of Morocco's commercial wheat imports from the U.S. were financed through the GSM-103 program. Loan repayment difficulties restricted Morocco's participation in the GSM-103 program in 1991 and 1992. The GSM-103 financing for Morocco was reinstated in May 1992 and continues to be a important factor governing the decision to import U.S. wheat (Ackerman 1993).

While the EU does not provide credit assistance as a community, credit is offered by some member countries. France has been the major EU wheat exporter to Morocco. An agency of French government, the Compagnie Française des Assurances pour le Commerce à l'Extérieure (COFACE), guarantees repayment of short-term credit. Ackerman states that in the Moroccan case the basic loan terms have been comparable to U.S. guaranteed loans: coverage for wheat sales has been about 95 percent of the principal for loan terms of five or more years.

It is also important to notice that quality of the imported wheats differ, so U.S. wheat and EU wheat are not perfect substitutes in the Moroccan market. The U.S. has exported primarily hard and soft red winter wheat to Morocco. Wheat varieties from European Union are classified by end use as superior breadmaking wheats (varieties with a consistently good baking value), standard breadmaking wheats, corrective wheats (strong or improving varieties), and wheats for other uses (animal feed or biscuit production). On average, wheat types exported from the EU to Morocco are reputed to be of lower protein content, higher moisture content, and higher test weight than U.S. wheats (Ackerman 1993).

Abbott et al. (1993) found remarkably similar institutions in agricultural markets of many less-developed countries (LDCs). For international wheat trade this means that parastatal trade monopolies in these countries exercise control over import levels of wheat, either directly or through licensing arrangements. In spite of the many critiques directed against typical agricultural trade policy regimes found in LDCs, parastatal marketing boards (or other public agencies controlling agricultural trade and domestic markets) seldom disappear (Abbott 1993). Morocco, which is the importing country used in our case study, is no exception.

The Office National Interprofessionnel des Céréales et Légumineuses (ONICL) is the parastatal agency controlling wheat trade in Morocco. It has been under study for reform or elimination under Morocco's structural adjustment program negotiated with the World Bank. Morocco, in fact, reformed its wheat trade regime in 1996 to comply with GATT and World Bank conditions, but ONICL continues to play a role in negotiating export subsidies from the EU and the U.S. EEP program.

Importing countries do not base their purchasing decisions solely on the price of the product. Earlier, it was mentioned that EU wheat and U.S. wheat differ in quality, and additional, useful information on Morocco's behavior as a wheat importing country can be gained by studying results of a survey conducted by Ackerman (1993). Her survey looks at factors influencing wheat import decisions of Morocco. Interviewed people included major decisionmakers responsible for Moroccan imports of wheat, users of imported wheat, and interested observers. Among the respondents were a representative of the Moroccan grain purchasing agency (ONICL), representatives from the Ministry of Finance, two importers, representatives of the national professional millers organization, one private miller, and the U.S. director of the Cereals Market Reform Project.

The official of ONICL and the two importers ranked the following four criteria as most important decisions: price, availability of credit, test weight quality standard, and government and trade relationships. The price factor was the most important for Moroccan grain buyers.

Prices bid by licensed importers take into account price subsidies from the U.S. and the EU. According to Moroccan importers and government officials, exporters experience greater uncertainty in obtaining approvals for EEP sales than in receiving subsidies for sales of EU wheat. In some years, this perceived uncertainty encouraged the procurement of wheat from EU locations rather than U.S. origins.

The second major factor affecting ONICL's purchase decisions is credit. The United States offers the Moroccan Ministry of Finance credit guarantees under GSM-103. On the EU side, the French government offers a line of COFACE-guaranteed credit each year for imports of all French products, including agricultural products. The Moroccan Ministries of Agriculture and Finance consider the loan terms, coverage, and relative interest rates when determining which governments' credit package is best suited for the Moroccan government.

Test weight is the most important quality factor for Moroccan importers.[9] It was indicated that test weight is a problem mainly for U.S. soft red winter wheat, which has test weights below those of other exporters' wheats. Representatives of the Moroccan Millers' Professional Association indicated that they would prefer wheat with a high-protein content and low-moisture level, and that they are planning to install testing laboratories at the ports to make their own more thorough tests of the quality of imported wheat.

The last major factor affecting purchasing decisions is government and trade relationships. Moroccan importers indicated that they have better relationships with European suppliers. In particular, Morocco has a long diplomatic and

[9] Importers seek wheat with test weights above 60 pounds per bushel.

economic relationship with France. In addition, the possibility of negotiating in the French language with suppliers in similar time zones was preferred.

These results of Ackerman's survey have provided useful insight into the importing country's behavior in the world wheat market. In addition, several other factors affect an importing country's purchasing decisions. One such general group of factors is called switching costs. These importing country's costs of switching from one wheat exporter to another might exist for many reasons. An importer incurs costs negotiating a contract or agreement with a supplier, and these transaction costs with a new exporter are higher than with an existing exporter. Another category is learning costs. There is more risk involved when buying from a new, unfamiliar source than when buying from an existing supplier. There also might exist political costs of switching between exporters. One would expect products supplied by political allies to be viewed differently from others. Actually, some of the survey's results, such as guaranteed credit programs and government relationships, can be viewed as forms of switching costs. For example, guaranteed credit programs to some extent lock Morocco in the EU and U.S., since COFACE-backed French loans can only be used to purchase French wheat and GSM-103 program can only be used to obtain loans to purchase U.S. wheat.

From the economic modeling perspective we can conclude that an importing country sees EU wheat and U.S. wheat as imperfect substitutes, implying a model with product differentiation. Another important aspect is that the importing country cannot switch freely between suppliers when making purchase decisions. These switching costs imply that current decisions are affected by history. Therefore, the decision making process is dynamic in nature. In later chapters, we develop an economic model of this market which attempts to take into account these aspects of international wheat trade.

## 2.4. Effects of the Uruguay Round GATT Agreement on Export Policies

The Uruguay Round of GATT negotiations were launched at the ministerial meeting in Punta del Este in September 1986. From the start, agriculture for the first time played a central role in the negotiations. At that time world prices were on a downward slide, reaching their lowest point for many years. Agricultural exports of the United States had been falling considerably, and farm support payments escalated (IATRC 1994). Export subsidy programs were reintroduced, and trade disputes became more common and more bitter. In the European Community, subsidized exports were the main outlet for surplus production, at an increasing cost for the Community's budget. Other exporters of agricultural goods began to suffer under the burden of the subsidized export market competition of the two agricultural "super-powers". These conditions in the world markets made it easier to reach a general consensus that it was necessary to reform policies in order to achieve trade liberalization in agriculture (IATRC).

In July 1987, the United States initially proposed to phase out over a ten-year period all agricultural import restrictions and all subsidies that directly or indirectly affect trade. The EC offered a more cautious proposal involving a more modest, phased reduction in support to agriculture.

Given the very wide gap between the negotiating positions of the EC and the U.S. it proved extremely difficult to reach agreement. The Mid Term Review meeting, originally convened in Montreal in December of 1988, failed to break the impasse. When the Mid Term negotiations were resumed in Geneva in April 1989 agreement was reached on a mid-term package which involved a freeze in current domestic support and protection levels. More explicitly, an engagement was made not to intensify tariff and non-tariff access barriers, and to freeze support prices to producers (OECD 1995). However, reductions of export subsidies proved to be the most difficult task. The EC in particular was reluctant to accept any specific limitations. This point was a major factor in the collapse of the ministerial meeting held in Brussels in December 1990 to bring the Round to a close (IATRC).

Soon after the GATT failure in 1990, EC Commissioner for Agriculture, Ray MacSharry, proposed a fundamental reform of the CAP. Within about a year the Commissioner pushed through his plan for reform. In May 1992, the EC's farm ministers agreed to (1) cut cereal support prices, (2) shift away from price supports to direct income payments, and (3) link farmers' payments to a set-aside program which aims to remove 15 percent of total arable land from production. Thus, the CAP reform, by reducing the need for EC's export subsidies and trade barriers, provided much desired help for the Uruguay Round GATT negotiations.

Concurrent with the CAP reform process, GATT negotiations resumed. In 1991, the agreement in principle to accept discipline in each of the three areas of import access, domestic support and export subsidies was achieved. From the end of 1991 onwards the negotiations on agriculture continued on the basis of the Draft Final Act which had been put forward by Arthur Dunkel, then Director-General of the GATT. This paper put forward specific quantitative actions and measures designed to strengthen trade disciplines in each of the three areas which had been accepted as essential and integral parts of a meaningful agreement on agriculture (OECD).

Although the EC's CAP reform opened the possibility of a solution to the agricultural negotiations, several aspects of the Dunkel Draft remained problematic. These related to the size of the export subsidy reductions. The issues proved highly contentious and it was only after long bilateral discussions between the U.S. and the EC that an agreement was reached. In the so-called Blair

House Accord a smaller reduction in the volume of export subsidies was agreed, relative to the original Dunkel Draft. Later, in the last minute negotiations in December 1993, some flexibility was granted in the use of base period from which annual export subsidy reductions are made (OECD).

Detailed country schedules were negotiated by the 15th December 1993 and were verified in the months leading up to the ministerial meeting in Marrakesh in April 1994 (OECD). Country schedules of the EU and U.S. are presented in the next section.

### 2.4.1. Export Subsidy Reduction for the EC and U.S.

The ability of countries to define specific limitations on the volume and value of export subsidies in agriculture was one of the main issues under discussion in the Uruguay Round negotiations. The Agreement on Agriculture bans new export subsidies, but existing subsidies are allowed to continue, subject to reduction. The terms of export subsidy commitment call for a 21 percent reduction in the quantity of subsidized exports and a 36 percent cut in the expenditure on export subsidies during the six-year implementation period[10]. Where the volume of subsidized exports in the more recent years was higher, countries could generally use the average 1991-92 export subsidy levels as starting points for reductions, instead of the original 1986-90 base period (the front-loading provision). However, for the final year of the implementation period, volumes and values have to be the same as they would have been had the earlier base period been retained.[11] While this adjustment was important in gaining final agreement for the GATT negotiations, it allows the EC and the U.S. to use significantly larger export subsidies in wheat throughout the implementation period than would have been the case under original provisions of the Dunkel Draft (OECD).

Schedules of export subsidy commitments state the maximum level of export subsidies allowed to exist during the implementation period. In the cereals sector, the commitments are divided into two categories: wheat/wheat flour and coarse grains. The details of the value and volume commitments in wheat for the European Union and for the United States are illustrated in Table 2.1.

[10] For developing countries the reductions are smaller, amounting to a 14 percent reduction in the quantity of subsidized exports and a 24 percent cut in the expenditure on export subsidies during the ten-year implementation period.

[11] Therefore, when reductions are calculated from the 1991/92 base level, the reduction in the quantity of subsidized U.S. wheat exports is 32 percent of 1991/92 base level (instead of 21 percent) and the reduction in the expenditure on U.S. wheat export subsidies is 57 percent (instead of 36 percent). Similarly for EU wheat, the reduction in the quantity of subsidized exports is now 34 percent and the reduction in the expenditure on export subsidies is 49 percent.

*Table 2.1. EU and U.S. Commitments on Wheat Export Subsidies.*

| Average base level 1986-90 | 1991-92 | Commitments 1995/96 | 1996/97 | 1997/98 | 1998/99 | 1999/ 2000 | 2000/ 2001 |
|---|---|---|---|---|---|---|---|
| | | Annual quantity commitments of the EU (1000 tons) | | | | | |
| 17 008 | 20 255 | 19 119 | 17 982 | 16 846 | 15 709 | 14 573 | 13 436 |
| | | Annual value commitments of the EU (million ECUs) | | | | | |
| 1 783 | 2 255 | 2 069 | 1 884 | 1 698 | 1 512 | 1 327 | 1 141 |
| | | Annual quantity commitments of the U.S. (1000 tons) | | | | | |
| 18 382 | 21 449 | 20 238 | 19 095 | 17 952 | 16 809 | 15 665 | 14 522 |
| | | Annual value commitments of the U.S. (million US$) | | | | | |
| 568.4 | 855.2 | 765.5 | 685.2 | 604.8 | 524.5 | 444.2 | 363.6 |

Sources: CAP Monitor 1996, USDA.

In addition to GATT commitments, the 1996 Farm bill limited total EEP funding by the U.S. even more during the first three years of the GATT implementation period. The limits are $350 million in fiscal year 1996, $250 million in 1997, $500 million in 1998, $550 million in 1999, $579 million in 2000, and $478 million in 2001. These restrictions are not surprising when we look at the context in which the additional voluntary restrictions were made. No EEP-bonuses were awarded since July 1995. The EU was using export taxes instead of export subsidies on wheat exports, and world grain storage was lower than ever before. Therefore, it is very unlikely that high (if any) export subsidies will be needed during the first few years of the GATT implementation period. On the other hand, it is much harder to predict what will happen after those first few years. Export subsidies could reemerge if world prices fall, and GATT constraints might then become binding. That is why we do not find any additional voluntary restriction made by the U.S. for those last three years of the GATT implementation period.

## 2.5. Noncooperative Strategic Interaction and Market Power in International Wheat Trade

Reducing export subsidies was a major accomplishment of the latest GATT Agreement. The Uruguay Round made progress, but activist government policies remain a basic feature of world trade in wheat. The failure of GATT to eliminate export subsidies can be seen as a result of countries' making their decisions based on their perceived self-interest, and not collaborating, which could have led to improved welfare of the world. A Prisoner's Dilemma- type situation occurs in which each country is worse-off because all countries subsidize their exports heavily (Kennedy et al. 1994).

Next, some examples are given to illustrate how two "superpowers", U.S. and EU, influence each other's and other exporters' policies. Understanding of international wheat market behavior and policy impacts requires methods that account for strategic interactions of these market agents.

It is not difficult to find suggestive evidence on noncooperative strategic interaction between the European Union and the United States in international wheat trade. One of the first obvious signs of this behavior in recent history happened in 1983 when the U.S. sold wheat flour to Egypt at a highly subsidized price. An export payment was made to U.S. wheat millers under an agreement between the U.S. and Egyptian government that provided for the sale of flour equal to one million metric tons of wheat. Wheat was released to flour millers from CCC stocks to enable millers to contract for sale and delivery to the Egyptian market without financial losses. Actual export flour prices averaged about $138 per ton (compared with U.S. wheat flour prices of $250-$260 per ton) (Grigsby and Jabara 1985). This "largest flour sale in history" was arranged to capture the Egyptian wheat market from the EC (Gardner 1996).

In May 1985 the U.S. responded to "unfair trade practices of the EC" (export subsidies) by announcing the EEP. This was the beginning of an era which is often called the grain subsidy war (Libby 1992). In the early years, the main stage of operations was wheat trade to North Africa. Since then, the program has been broadened to include more products and countries. Both the United States and the European Union claimed to be matching the other's export subsidies. Figure 2.6 shows trends over time in EC and U.S. wheat subsidies from 1986/87 to 1995/96 that are consistent with this claim.

By looking at the underlying criteria used to fix export restitutions in the EU and EEP bonuses in the U.S., it is clear that noncooperative strategic interaction between the EU and the U.S. exists. As an example, part of the statement given

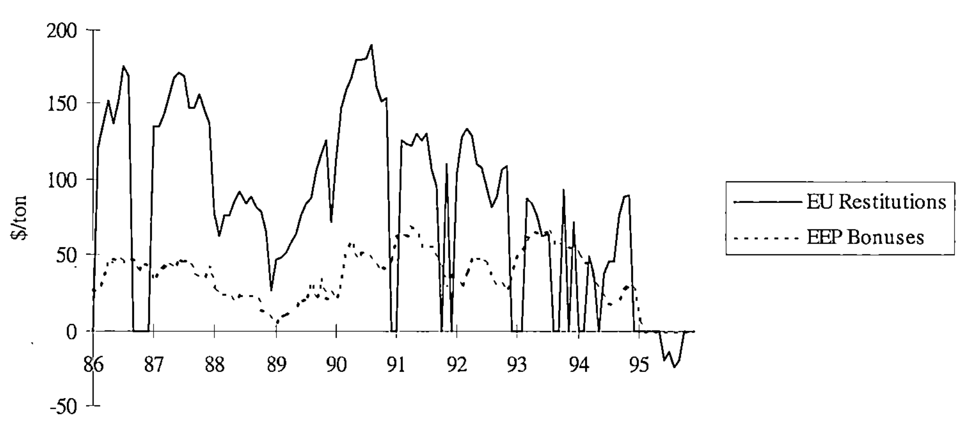



*Figure 2.6. EC and U.S. Wheat Export Subsidies, 1986/87-95/96.*

in May 25, 1995 by Under Secretary for Farm and Foreign Agricultural Services, Eugene Moos, follows:

> "The Export Enhancement Program (EEP) helps the United States meet subsidized competition in targeted markets – particularly competition from the European Union. The EEP has in many cases, increased, or prevented further declines, in U.S. exports; it has challenged unfair trade practices by others; and it has pressured our trading partners to engage in serious negotiations on bilateral and multilateral agricultural trade issues. The EEP will remain an important part of our trade policy arsenal, and we will continue to use it – as the administration pledged – to the maximum extent permitted under the subsidy reduction commitments provided for in the GATT Uruguay Round Agreement" (United States Congress 1995).

Another aspect that makes the world wheat market imperfectly competitive is the fact that exporting firms have the potential to exercise market power to influence the market price. Several studies have looked at this issue. Drawing on the industrial organization literature, Caves and Pugel (1982) were among the first to study concentration and market power of international wheat exporting firms. In their analysis it was concluded that there was not sufficient evidence to declare that imperfect competition existed among international wheat exporting firms. Thus, their conclusion was in contrast with the public perception of imperfect competition in this sector. However, Caves and Pugel did not offer any direct test of the relationship between pricing behavior and market structure. Later, Patterson and Abbott (1994) provided this test. Their paper analyzed the relationship between export pricing behavior and market structure in the U.S. wheat and corn sectors in which the data for wheat covered 98 destination countries for U.S. wheat. In contrast to Caves and Pugel, their results suggest that the pricing behavior of U.S. wheat exporting firms does not reflect pure competition. However, Patterson and Abbott also add that the magnitude of the exporting firms market power is quite small, supporting our perception that it is exporting countries' governments instead of firms that exercise the greatest power on the market.

A market structure study by McNally (1993) provides another piece of evidence on the imperfectly competitive (oligopolistic) nature of the U.S. wheat exporting firms. Her study focused on those exporting firms who participated in the Export Enhancement Program from 1985 to 1989. McNally calculated two measures of firm concentration: firm concentration ratio and Herfindhal-Hirschman Index (HHI). The EEP data four-firm concentration ratio, CR4= 69 %, was about the same as the one found by Patterson and Abbott (CR4=69.8 %). According to Connor et al. (1985) categorization the industry comprised of wheat exporting firms participating in the EEP is highly concentrated oligopoly. The second measure of industry concentration discussed by

McNally was the Herfindhal-Hirschman Index. The study stated that HHI for firms participating in the EEP is HHI=1398. According to standards established by the Federal Trade Commission, McNally's HHI-value indicates that this wheat export industry in the U.S. is moderately concentrated.

The above studies have looked at the market power of firms exporting U.S. wheat. They suggest that these firms have a degree of market power to influence price. Similar studies and/or publicly available data for subsidized wheat exports from the EU do not exist. We have some insight on concentration based on several conversations with EU wheat trade experts. The major multinational wheat exporting firms that participate in the EEP also trade EU wheat. However, a large portion of EU wheat is traded by French exporting firms (e.g. Soufflet). In general, it is believed that EU wheat exports are approximately equally concentrated (or possibly a little less concentrated) than U.S. wheat exports.

If we consider EU wheat exports to Morocco, which is the importing country in our case study, we notice that France has been the dominant exporter. From 1988/89 through 1991/92 it has covered over 80 percent of EC wheat exports to Morocco. A large portion of wheat exports from France is handled by French exporting firms. On the other hand, U.S. wheat exports to Morocco are mainly traded by large American grain companies. Because of this concentrated market structure we have suggestive evidence that firms have a degree of market power to influence price. Therefore, from the economic modeling perspective it seems plausible to assume that exporting firms of EU and U.S. wheat are involved in a price competition game in the imperfectly competitive Moroccan wheat market.

## 2.6. Conclusions

This chapter has shown that the European Union and the United States are two noncooperatively behaving "super-powers" in the international wheat market whose actions in the market have an influence on each other's agricultural policies as well as on world market prices. The most significant strategic variable has been an export subsidy, on which the GATT Uruguay Round Agreement has set upper bounds. The chapter has also provided some evidence that exporting firm level price competition is oligopolistic (imperfect) in nature. Finally, the chapter has provided useful insight into an importing country's behavior in the world wheat market. The importing country sees the products from different suppliers as imperfect substitutes. Another important aspect is that an importing country faces costs when switching between suppliers in making purchase decisions. These switching costs imply the decision making process is dynamic in nature. In later chapters we develop an economic model which attempts to take into account these aspects of international wheat trade.

# CHAPTER III

## LITERATURE REVIEW

National agricultural policies, particularly those of major trading countries or country groups (e.g., the European Union and the United States), often have come into conflict due to their interaction through international trade. Agricultural trade policy is largely a consequence of policy instruments put in place to achieve domestic policy goals (e.g., the levels and stability of farm incomes and food security). Even after the Uruguay Round GATT Agreement, international trade in agricultural products continues to be influenced by agricultural trade policies, and by export subsidies (or export taxes) in particular. This situation persists despite the substantial amount of agricultural trade policy analysis that has been conducted over at least the last twenty-five years showing losses in national and world income which are incurred due to export subsidies (e.g. Abbott 1985, Anania et al. 1992).

In the framework traditionally used to analyze trade issues, a neoclassical perfectly competitive model, export subsidies always reduce the welfare of the subsidizing country. This means that either decisionmakers are acting irrationally or the assumptions of the competitive model are in error. Paarlberg (1984) claims that the following four assumptions are critical to the outcome of the traditional perfectly competitive model of international trade:

(1) all goods are homogeneous;
(2) the model is static and characterized by certainty;
(3) all political interest groups have equal influence on the policy maker; and
(4) all agents are price takers – thus the subsidy is exogenous to the system.

Developments in international trade theory have relaxed these assumptions of the traditional model and therefore helped us in our attempts to understand why policymakers might use export promotion policies.

The purpose of this chapter is to survey these major developments in international (agricultural) trade modeling and in industrial organization literature relevant to the characteristics of world wheat market. The chapter begins with a critical review of the traditional agricultural trade modeling literature.

International wheat markets are believed to be imperfectly competitive. Chapter II provided some evidence that exporting firm level price competition is oligopolistic (imperfect) in nature. At the country level a few exporting countries dominate the supply of wheat in the world market. The governments of two "superpowers", the EU and the U.S., follow carefully each others' behavior in the market when setting their export subsidies. One objective of this research is to develop an international wheat market model in which we can capture real world strategic interaction between the participants in this market. To do this requires that we use the tools of game theory in the model building process. Therefore, section 2 will review modeling techniques for empirical game-theoretic models. Then, in the following section, agricultural trade modeling literature that uses these tools is reviewed.

Next, we note that politics and special interest group pressures have important effects on trade policies. Political economy explanations of trade policies are important, because they may help to develop an understanding of why subsidies rather than taxes are used as trade interventions.

Chapter II also claims that an importing country cannot switch freely between suppliers when making purchase decisions. For example, the transaction costs that an importer faces when negotiating a contract with a new supplier are higher than with an existing exporter. In addition, more risk is involved when buying from a new source than when buying from an existing supplier. Guaranteed credit programs, government and trade relationships, as well as language preferences also create switching costs. Therefore, the last section of this chapter will provide some basic background on switching cost theory.

## 3.1. Traditional Agricultural Trade Models

The purpose of this section is to review the literature on traditional agricultural trade models, used by institutions like U.S. Department of Agriculture (USDA) and Organization for Economic Cooperation and Development (OECD) for policy analysis, projections, forecasts, and as a means of gaining a better understanding of the economic forces and policy regimes that determine agricultural trade.

Traditional approaches to agricultural trade modeling can be divided into three different categories: 1) spatial equilibrium models, 2) nonspatial equilibrium models, and 3) trade flow and market share models (generally of the Armington-type). These models are generally static and assume perfect competition. The first two categories also assume a homogeneous good, in contrast to the last category where products are differentiated by origin. Surveys of this literature are provided by Thompson (1981), Thompson and Abbott (1982), and Sarris (1981).

### 3.1.1. Spatial Equilibrium Models

In his review of agricultural trade models, Thompson (1981) states that spatial price equilibrium models were one of the most popular approaches to agricultural trade modeling, particularly for purposes of trade policy analysis. Thompson supports this statement by citing nearly three dozen spatial equilibrium models of international markets for wheat, rice, corn, sugar, pork, beef, oranges, rapeseed, and peanuts. The feature that distinguishes these models from the nonspatial equilibrium models, discussed next, is that spatial equilibrium models endogenize trade flows and market shares.

An example of a spatial equilibrium model is the world wheat trade model of the U.S. Department of Agriculture (Dixit and Sharples 1987). There also exists a spatial equilibrium version of USDA's SWOPSIM model, although the original model is nonspatial (Roningen et al. 1991).

One of the principal arguments for use of the spatial equilibrium models was that they generate trade flows and market shares, variables that often are of interest to the users of these models. However, this appears to be a questionable advantage, because spatial equilibrium models have not been very successful in explaining real world trade flows. A number of reasons can be presented to explain these deviations, all concerning invalid assumptions made in the spatial equilibrium formulation. One explanation could be that the spatial equilibrium models are designed to model trade flows for homogeneous products, but the product might not be perfectly homogeneous. For example, in the international wheat market there are many varieties of wheat, each with different principal uses. They are not perfect substitutes for one another. Moreover, importing countries may differentiate among exporting countries on historical or political grounds. Therefore switching between suppliers may not be as easy as these models assume.

Another problem is that spatial equilibrium models are usually static. Some users of trade policy analyses need information on the time path of adjustment of supply, disappearance, and price.

A very problematic assumption in spatial equilibrium trade models is their assumption that all trading countries behave in a perfectly competitive market. As was shown in Chapter II, international wheat exports are in the hands of very few countries and firms. In addition, several importing countries as well as exporting countries also have either parastatal agencies or private monopolies taking care of their foreign trade. This suggests that the perfectly competitive market assumption of the spatial price equilibrium formulation may not adequately approximate the behavior of the different market participants in international grain markets. Nevertheless, the fact that spatial equilibrium models generally do not do very well at accomplishing one of their principal goals – to account for trade flows – casts doubt on the justification for using a spatial equilibrium formulation when trade flows are of particular interest.

One advantage of the spatial equilibrium formulation of an agricultural trade model is that it is an efficient means of examining the effects of changes in transport costs on the net trade positions of trading regions. However, because trade flows are sensitive to small changes in transport costs (as well as to policy variables) in these models, one must interpret the predicted effects on trade flows with caution. Such doubts with respect to the spatial price equilibrium approach have raised a number of questions concerning its adequacy for purposes of policy analysis (Thompson 1981).

### 3.1.2. Nonspatial Equilibrium Models

Nonspatial price equilibrium models represent a special case of spatial equilibrium models. Trade flows between specific pairs of countries are suppressed and only the net trade position of each trading country is found. Therefore, it is not possible to study effects of bilateral agreements, bilateral quotas or targeted subsidies, which are frequently used in international agricultural trade. The main advantage of nonspatial price equilibrium models is that they are easier to solve than are the spatial equilibrium models. Nonspatial equilibrium models are solved as a system of simultaneous equations rather than by optimization.

A number of the nonspatial equilibrium models explicitly include detailed domestic market models and price linkage equations, rather than merely reflecting the behavior of each country by a single import or export equation.

An example of nonspatial equilibrium model is USDA's SWOPSIM model (Roningen et al. 1991). The Iowa State University FAPRI trade model, and the grain-oilseeds-livestock (GOL) model of the USDA also belong to the class of nonspatial price equilibrium models.

### 3.1.3. Armington-Type Trade Flow and Market Share Models

The class of differentiated product models recognizes that individual commodities are not perfectly homogeneous. Thus, the first problematic assumption mentioned by Paarlberg is relaxed. There may exist physical differences in quality, or the product may be differentiated in the eyes of the importer owing to such intangible factors as reliability of supply or political inclination of the government of the importing country. Many trade models treat imported commodities as imperfectly substitutable for the "same" commodities produced domestically. Alternatively, the same commodity from each different origin is treated as a different good.

Armington (1969) developed a theory for a trade model in which goods are differentiated by country of origin. This approach assumes that utility is weakly separable and homothetic, such that a buyer's (importer's) decision process may be viewed as a two-stage utility maximization procedure. In the first stage the importer decides how much of a particular commodity to import. In the second stage, given the total amount imported, the importer decides how much to import from each supplier. To simplify the model and reduce the number of parameters to be estimated, it further assumes that the total quantity of the product imported has a constant elasticity of substitution (CES) specification. This specification implies weak separability between different import sources.

The Armington approach permits the calculation of cross-price elasticities between imports from all sources using estimates of the aggregate price elasticity of demand for imports, a single elasticity of substitution, and import market shares.

The Armington approach was first applied in agricultural trade modeling by Grennes et al. (1977). Abbott et al. (1988) also used this approach to explain why the Russian grain embargo caused price movements in a direction opposed to that predicted by spatial equilibrium models. Hjort (1988) recognizes also quality requirements, and therefore introduced a three-stage version of Armington-type model. The additional stage in her model is the second stage, where the importer determines what quality class(es) of wheat will optimally satisfy wheat import demand. Also, Haley (1995a, 1995b), in his studies on EEP, uses this three-stage version of the Armington-type model.

Armington-type models exhibit much smoother changes in trade shares than spatial equilibrium models, and account more adequately for observed trade flows than the spatial equilibrium model. On the other hand, homotheticity and separability of the utility function are strong assumptions. These restrictions were tested and rejected using data from the international cotton and wheat markets by Alston et al. (1990).

### 3.1.4. Evaluation and Critique

All of the critical assumptions stated by Paarlberg are made in these models, except the homogeneous product assumption, which is relaxed in the Armington approach. One main concern for our research is that all the models discussed make the perfect competition assumption. It has been demonstrated in several studies that this assumption is not realistic for international agricultural trade (see Chapter II). Since the late 1970's, the development of agricultural trade models with imperfect competition characteristics has been very rapid. Some of these models use game theoretic tools to study behavior in agricultural markets. Therefore, empirical applications of game theory are reviewed next.

## 3.2. Empirical Games and International Trade

International wheat markets are believed to be imperfectly competitive. Large exporters and importers have potential market power. When we have an imperfectly competitive market structure (e.g., an oligopolistic market structure) a firm or country no longer meets a passive environment (Tirole 1988). One challenging objective of this research is to develop an international wheat market model in which we capture real world strategic interaction between the participants in the market. To do this requires that we use the tools of game theory in the model building process. Therefore, it is useful to see how game theory can be used and has been used in industrial organization (IO) and trade theory, and how it has been applied to empirical studies in the trade literature.

In economics, the techniques of noncooperative game theory are most widely used in industrial organization (IO). Throughout the 1980s the bulk of research effort was devoted to development of a new body of theory which rests upon use of game-theoretic oligopoly models. This so called new IO was a break from the past tradition of modeling markets as either competitive, in which case firm interactions could be safely ignored, or monopolistic, where interactions were assumed absent.

Since the beginning of the 1980s international trade economists have also sought to incorporate oligopoly and other forms of imperfect competition into the analysis of international trade and trade policy in order to examine (or represent) important empirical regularities and policy concerns. The ability of traditional trade theory to do this was found to be inadequate. The assumption of perfect competition was unrealistic and reasons for trade, such as different factor endowments between countries or comparative advantage, were not able to explain outcomes like intra-industry trade and the high volume of trade between similar countries. Furthermore, such models failed to successfully incorporate important policy-relevant considerations, such as firm-level increasing returns to scale, learning by doing, R&D, and inter-government and/or inter-firm strategic rivalries. Because of these problems the "new" trade theory was born.

The new trade theory is mainly an application of the analysis of strategic behavior developed in the new IO literature. Therefore, it also uses game theory as a tool in its analysis. This new trade theory simultaneously models imperfect competition and international trade. A number of good surveys of trade policy with imperfect competition (which apply the tools of game theory) have been written (see for example, Grossman and Richardson (1985), Dixit (1987), Krugman (1989), Krishna and Thursby (1990) and Brander (1995)).

Game theory is a theory of strategic interaction. As Harsanyi (1995) states in his Nobel Prize lecture, it is a theory of rational behavior in social situations in which each player has to choose his moves on the basis of what he thinks the other players' countermoves are likely to be.

Games in Game Theory can be divided into two categories: 1) noncooperative games and 2) cooperative games. Almost all the applications of game theory in international economics (and in economics in general) fall into the noncooperative category. Fudenberg and Tirole (1991) describe the idea of noncooperative games as follows:

> "The word noncooperative means that the players' choices are based only on their perceived self-interest, in contrast to the theory of cooperative games, which develops axioms meant in part to capture the idea of fairness. Noncooperative does not mean that

players do not get along, or that they always refuse to cooperate. Noncooperative players motivated solely by self-interest can exhibit cooperative behavior in some settings."

The models of noncooperative game theory can be divided into four broad groups. One of the groups is static games with complete information. In static games of this type, all agents move simultaneously, so no agent has the opportunity to react to another's move. Another way to say this is that a static game is a model of interactive decision-making in which each decision-maker chooses his plan of action once and for all, and these choices are made simultaneously (Osborne and Rubinstein 1994). Complete information implies that each agent knows everything there is to know about the structure of the game – not only about his own choices, but also the choices available to other agents. A second group of games is dynamic games with complete information. In these agents adopt strategies in which their current actions depend upon the past actions of the other agents.

The last two groups of noncooperative game theory are the static games of incomplete information and the dynamic games of incomplete information. A distinction between games with complete and with incomplete information is based on the amount of information the players will have about the basic structure of the game. Lack of information about the structure of a game can take many different forms. The players may lack full information about the other players' (or even their own) payoff functions, about physical or the social resources, about strategies available to other players' (or even themselves), about the amount of information the other players have about various aspects of the game, and so on (Harsanyi 1995). That is to say, the distinction is based on the amount of information the players will have about those characteristics of the game that must have been decided upon before the game can be played at all.

Harsanyi (1967, 1968a-b) presented a way to convert an incomplete information game into a game of complete information. He did this by introducing a prior move by nature that determines players' "types" (see for example Harsanyi 1995). In the converted game the incomplete information becomes imperfect information about nature's moves, so the converted game can be analyzed with standard techniques. Now the distinction is made between games with perfect and with imperfect information[1]. In games with perfect information, all players will have full information at every stage of the game about all moves made at earlier stages, including both personal moves and chance moves (i.e., nature's moves). In contrast, in games with imperfect information, at some stage(s) of the game the players, or at least some of them, will have only partial information

[1] Note that this distinction is different from the earlier distinction between games with complete and with incomplete information.

or none at all about some move(s) made at earlier stages (Harsanyi 1995). A game with imperfect information is also called a Bayesian game.

Since our goal in this research is to build a dynamic, game theoretic model of the international wheat market, we need to examine modeling techniques for empirical game-theoretic models. Both static and dynamic games are studied. Static games are described first because the majority of the research has used this approach.

### 3.2.1. Static Games

For concreteness, let us say that players are firms, and when the game is static their payoffs are single-period profits. In general, a player's strategic variable can be price, quantity, advertising, capacity or any other variable under the firm's control. Only price and quantity competition are considered here. Discrete changes such as entry and exit are ignored.

In a competitive industry, market prices are exogenous. When an input or output is variable (optimally allocated) its shadow price equals its market price. Moreover, each firm can make its decision in isolation. This is true because its payoffs do not depend on the actions of other players in the market. In an oligopoly, in contrast, output prices are endogenous, which raises two issues. First, even when an output is optimally chosen, market and shadow prices may not be equal. This means that the competitive profit function, which depends only on market prices, must be modified. Second, profits depend on other firms' choices, firms make optimal decisions conditional on rivals' actions.

Suppose that firm $i$ is large enough to have market power in its product market. The price/quantity relationship is expressed by inverse demand functions,

$$p^i = P^i(q), \tag{3.1}$$

where $q = \sum_i q^i$ is aggregate output sales in the market. Firm $i$'s net profit, or total revenue minus total cost, is

$$\pi_0^i(q) = P^i(q)q^i - c^i(q^i), \tag{3.2}$$

where $c^i(q^i)$ is $i$'s cost function. Notice that rival outputs appear in each function. It is assumed that each $\pi_0^i$ is concave in $q^i$.

The solution concept is Nash equilibrium[2], in which all firms choose their strategies such that each firm's strategy, $s^i$, maximizes that firm's payoff, conditional on the strategies chosen by other firms

$$\max_{s^i} \pi_0^i \qquad i = 1,\ldots,n. \tag{3.3}$$

Although it is easy to write down the maximization problem (3.3), it is not immediately obvious what it means. For the problem to be well defined, it is necessary to know what sort of game the firms are engaged in (e.g., Cournot, Bertrand, or dominant firm with competitive fringe). For example, in the Cournot game the strategic variable $s^i$ is the quantity variable $q^i$. In the Bertrand game it is the price variable $p^i$. To see the difference between these games, it is useful to examine the first-order condition with respect to $q^i$ conditional on rival choices for the above maximization problem:

$$P^i + \frac{\partial P^i}{\partial q^i} q^i + \left[ \sum_{j \neq i} \frac{\partial P^i}{\partial q^j} \frac{\partial q^j}{\partial q^i} \right] q^i - \frac{\partial c^i}{\partial q^i} = 0. \tag{3.4}$$

The reason the unusual terms $\partial q^j / \partial q^i$ appear in (3.4) is that, for a Nash equilibrium, partial derivatives are taken holding other firms' strategies constant, and the strategic variable need not be $q$. The term $\partial q^j / \partial q^i$ is called a conjectural variation of firm $i$ about firm $j$. With Cournot competition, in which strategic variables are quantities, these terms equal zero.

Suppose, in contrast, that firms' strategic variables are prices, $p^i$. In this case, each player conjectures that his opponents' prices will be unaffected by his choice. It can be shown (see for example Slade (1995)) that the Bertrand conjecture for the differentiated products case is $\partial q^j / \partial q^i = -\left(s^j \varepsilon^{ji}\right) / \left(s^i \varepsilon^{ii}\right)$, where $s^i$ is firm $i$'s market share; $\varepsilon^{ii}$ is the partial own-price elasticity of demand (holding rival prices constant), $\varepsilon^{ii} = -\left(\partial q^i / \partial p^i\right)\left(p^i / q^i\right)$; and $\varepsilon^{ji}$ is the partial cross-price elasticity of demand, $\varepsilon^{ji} = -\left(\partial q^j / \partial p^i\right)\left(p^i / q^j\right)$. For the homogeneous product case without capacity constraint the Bertrand conjecture is minus one. This is equivalent to a perfectly competitive model, since the first-order condition reduces to price equals marginal cost.

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[2] In a Nash equilibrium, no player would find it in his or her interest to deviate unilaterally from a Nash equilibrium strategy. If a set of strategies is not a Nash equilibrium then at least one player is not consistently thinking through the behavior of the other players. That is, one of the players must expect the other player not to act in his own self-interest (the assumption of noncooperative behavior is not met).

These conjectures vary considerably with different strategic variables. Therefore, when a static game framework is applied to policy analysis it becomes critical to correctly choose the strategic variable (or conjecture). As an example we can look at the strategic trade policy literature. First, Brander and Spencer (1985) showed in their two exporting country model that under Cournot competition national welfare can be increased, relative to that with free trade, when one of the governments pre-commits to intervention and does so in the form of an export subsidy. Subsequently, Eaton and Grossman (1986) showed that the Brander and Spencer conclusion was sensitive to the strategic variable used by export firms. In particular, they showed that if the firms competed on price and played a Bertrand game, then an export tax was the optimal policy.

### 3.2.2. Dynamic Games[3]

Static models can provide useful summary statistics concerning the outcomes of oligopolistic interactions, but they are only the first step in the economist's attempt to understand strategic interactions. To capture more complex strategic behavior we need to look at dynamic models. Fudenberg and Tirole (1986) identify two reasons for employing dynamic models of oligopoly in preference to static models. First, the behavior and performance of a mature industry depend crucially on the history of that industry, and this history-dependence is best modeled in explicitly dynamic models. Second, nonstationary industries, whether growing or declining, require explicitly dynamic models.

There are many ways to introduce dynamics into games. Only one class of dynamic games, the state-space game, is examined here. Most empirical dynamic game analysis falls into this class[4].

A state-space game can also be called a difference game or a differential game. It is a difference game in discrete time and differential game in continuous time. In these games payoff-relevant history is collapsed into one or more variables, the state. Moreover, the players, who have long time horizons, anticipate rival reactions to all of their actions. Since optimal control problems constitute a special class of (infinite) dynamic games with one player and one criterion, the mathematical tools used for such problems are applied in dynamic game theory, as well.

In these games certain variables are chosen by the players in every period. Such variables, $x^i(t)$, are called players' controls (actions). There are many

[3] This introduction to state-space games follows the presentation of Slade (1995).

[4] Another class of dynamic games are repeated games with time-independent payoffs. With repeated games, payoff functions are constant over time, but strategies can depend on payoff-irrelevant history.

possibilities for controls. For example, players' might choose output, investment in capacity, advertising effort, tariff level, or export subsidy level. In addition to the controls, there is a state vector, $k(t)$ that is common to all players. It denotes the position, or state, or payoff-relevant history of the game at date $t$. This state could be stock of physical capital for example.

The relationship between the state and controls is governed by the state equation of the dynamic game. This equation is a difference equation in the discrete-time case and a differential equation in continuous-time case, hence the names difference game and differential game, respectively. To avoid confusion only the differential game structure is used below to explain the set-up procedure of a state-space game (for difference games see Basar and Olsder 1995). The state equations (equations of motion) of a differential game are

$$\frac{dk(t)}{dt} = f\big(k(t), x(t), t\big), \tag{3.5}$$

where $x(t)$ is the vector of controls. The state equations are assumed to be continuously differentiable.

Each firm earns an instantaneous profit that depends on both the current state and controls,

$$\pi_t^i = \pi^i\big(k(t), x(t), t\big). \tag{3.6}$$

The above equation shows that profits depend on history only as it is embodied in the current state. Therefore, it is irrelevant which way the state evolved. It is assumed that equation (3.6) is differentiable and concave in $x^i(t)$.

The objective function of player $i$ is his discounted profits,

$$V^i = \int_{t=0}^{T} \Pi^i\big(k(t), x(t), t\big)dt + \upsilon^i\big(k(T), T\big), \tag{3.7}$$

where $T \leq \infty$ is the duration of the evolution of the game, which is specified a priori. $\Pi^i$ is the instantaneous profit times a discount factor, and $\upsilon^i$ is the terminal payoff which depends on the state at the end of the game.

In order to specify a nonzero-sum differential game, the next necessary ingredient is an information structure. The terms open-loop, feedback, and closed-loop are used to distinguish between different information structure assumptions in dynamic games. Each player's strategy is a sequence of functions that map the players' information, $\Omega^i(t)$, into a choice of controls,

$$\{x^i(t) = \Psi^i(\Omega^i(t))\}, \qquad 0 \le t \le T, \tag{3.8}$$

where $\Psi^i$ is assumed to be continuously differentiable. Differences between information structure assumptions can be seen by looking at the contents of $\Omega^i(t)$. Players' information structure is an open-loop pattern when players cannot observe the state after $t = 0$ (i.e., they commit to their controls as of time zero). Strategies, therefore, are time paths for the actions that can depend on the initial conditions but are independent of the state. Furthermore, since an open-loop calculation only involves choice at time zero, it is essentially static.

In contrast, games with state-dependent strategies are fundamentally dynamic. If players can condition their strategies on other variables in addition to calendar time, they may prefer not to use open-loop strategies in order to react to exogenous moves by nature, and to possible deviations by their rivals from equilibrium strategies. Therefore, closed-loop and feedback strategies are rules for choosing controls as functions of the state as well as time.

The distinction between feedback and closed-loop information structure is that with feedback information, players know only the current state (payoff-relevant information) whereas a closed-loop information pattern includes the way in which the state has evolved (payoff-irrelevant information). Formally this can be stated as follows,

$$\Omega(t) = \begin{cases} \{k(0), t\} & \textit{open loop} \\ \{k(t), t\} & \textit{feedback, and} \\ \{k(\tau), 0 \le \tau \le t, t\} & \textit{closed loop.} \end{cases} \tag{3.9}$$

A Nash equilibrium in open-loop strategies is called an open-loop equilibrium (as with Cournot and Stackelberg equilibria, this is not really a new equilibrium concept but rather a way of describing a particular class of games). Open-loop equilibria coincide with subgame perfect equilibria[5], since the only proper subgame is the game itself. Feedback equilibria (i.e., Nash equilibria in feedback strategies) are usually required to be subgame perfect. When this is the case they are also known as Markov perfect equilibria. In contrast, closed-loop equilibria need not to be subgame perfect[6].

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[5] By definition, a subgame perfect Nash equilibrium for the extensive form game is a Nash equilibrium for the game that, also, gives a Nash equilibrium in every proper subgame of the game (Kreps 1990).

[6] Most empirical game models have used either open-loop or feedback information structure. Therefore, closed-loop equilibria are not studied here.

Control-theory techniques can be used to derive necessary conditions for differential games. A game in open-loop strategies is similar to $N$ simultaneous optimal-control problems, where $N$ is the number of players. A game with feedback strategies, in contrast, is similar to $N$ simultaneous dynamic-programming problems (or to $N$ control problems) where players recognize that other players' future choices are influenced by the state. In each case, the state equations are constraints on the optimization. To keep games more tractable, considerable differentiability has been assumed in the models[7]. To show equilibrium conditions, assume that player $i$ wishes to choose $x^i = \Psi^i(\cdot,\cdot)$ to maximize $V^i$ subject to the state equation and the initial condition $k(0) = k_0$. In the feedback equilibrium, the following necessary (first-order) conditions must be satisfied for each player $i$:

(3.10) $$\frac{dk^i}{dt} = f^i(k,x,t), \qquad k(0) = k_0$$

(3.11) $$\frac{d\lambda^{ij}(t)}{dt} = -\frac{\partial H^i}{\partial k^j} - \sum_{\ell=1,\ell\neq i}^{N} \left(\frac{\partial H^i}{\partial x^\ell}\right)'\left(\frac{\partial \Psi^\ell(k,t)}{\partial k^j}\right) \qquad \forall j = 1,\ldots,N$$

(3.12) $$\Psi^i(k,t) \in \arg\max_{x^i} H^i\left(k,x^i,x^{-i},\lambda^i\right)$$

(3.13) $$\lambda^{ij}(T) = \frac{\partial v^i(T)}{\partial k^j(T)} \qquad \forall j = 1,\ldots N,$$

where $H^i\left(k,x,t,\lambda^i\right) = \Pi^i(k,x,t) + \sum_{j=1}^{N} \lambda^{ij} f^j(k,x,t)$ is the Hamiltonian and $\lambda^i \equiv (\lambda^{i1}, \lambda^{i2},\ldots,\lambda^{iN})$ is the costate variable for player $i$. In contrast to static games, these shadow prices are marginal values of the state, not of current choice variables. However, as with static games, shadow prices are closely related to equilibrium strategies. In equation (3.11), $\partial\Psi^\ell/\partial k^j$ is the vector of

[7] Starr and Ho (1969a) restricted their attention to objective functions that are continuous and almost-everywhere-differentiable (i.e., piecewise continuously differentiable) functions of the state variables.

partial derivatives of player $\ell$'s strategy with respect to the $j$th component of the state, with the convention that the derivative of $H^i$ with respect to the vector $x^\ell$ (i.e., $\partial H^i / \partial x^\ell$) is a column vector. Note that the troublesome second term in (3.11) is absent in a one player game (i.e., optimal control problem) because $N=1$, and in an open-loop problem because $\partial \Psi^\ell / \partial x^j = 0$. So, whenever this term is nonzero we would expect open-loop and feedback solutions to be different (Starr and Ho 1969b).

Under the feedback information structure assumption, each agent takes into account the influence of his actions on the state, both directly and indirectly. The indirect effect occurs because the state enters other agents' decision rules and affects their future actions. The second term in equation (3.11) captures this fact that player $i$ cares about how his opponents will react to changes in the state. The problem is that games with feedback strategies become very difficult to solve. In particular, because of the cross-influence term in the costate-variable equation, the evolution of the shadow price of the $j$th state variable for player $i$ is determined by a system of partial differential equations, instead of by ordinary differential equations as in the one-player case. As a result, very few differential games can be solved in closed form.

It is clear from the above that both the first-order conditions and shadow-price equations can be very complex or even intractable for state-space games. Moreover, the functional forms for strategies and shadow prices are usually unknown. Therefore, most empirical research has focused on linear-quadratic (LQ) games, which have a closed form solution. LQ games are games for which the equations of motion are linear in the state and control variables and objective functions are quadratic in the state and control variables.

This review of dynamic games was done in the context of continuous-time dynamic games (i.e., differential games). This is a common approach in theoretical state-space models since it is mathematically more convenient (e.g. Slade 1995, Fudenberg and Tirole 1986). However, empirical works often use a discrete time dynamic game structure since that better illustrates some real world phenomena and/or because of data availability. To define a discrete-time dynamic game, equation (3.5) would be replaced by a difference equation and the integral in (3.7) by a summation. Then the equilibrium feedback solution is obtained by backward induction (Kydland 1975).

The empirical model of this dissertation uses a discrete-time dynamic game model to study international wheat trade. We study the subgame perfect equilibrium (Markov perfect equilibria), which, for a finite horizon model, is obtained by working backwards from the last period. Players' actions are conditioned on payoff-relevant information: the state. Players understand how their current behavior will affect players (themselves and others) in the future.

## 3.3. Imperfect Competition in (Agricultural) Trade Models

Since the beginning of 1980s international trade economists have sought to incorporate oligopoly and other forms of imperfect competition into the analysis of international trade and trade policy to capture important empirical regularities and observed policy regimes. A massive number of journal articles have been published in this area. The most relevant part of this literature for this dissertation is strategic trade policy. Brander (1995) defines strategic trade policy to be trade policy that conditions or alters a strategic relationship between firms. This very restrictive definition implies that the existence of strategic interaction between firms is a necessary precondition for the application of strategic trade policy. A broader definition, which also includes interaction between governments in otherwise perfectly competitive situations, is adopted here. The study of strategic trade policy is fundamentally an application of noncooperative game theory.

In spite of its problems, the simplicity of the static conjectural variations (CV) approach made it a popular tool in the 1980s. In this approach each country (firm) believes that if it increases its strategic variable by one unit, the representative other country (firm) will change its strategic variable by $\nu$ units. The parameter $\nu$ is the country's (firm's) conjectural variation; by allowing $\nu$ to vary, it is possible to represent a variety of industry behaviors. However, there are some strong objections to the concept of conjectural variations. For example, Helpman and Krugman (1989) state that the first objection to the conjectural variations approach is that it seems to be an awkward compromise between static and dynamic analysis.

A Nash equilibrium in either the Cournot or Bertrand case can be thought of as the outcome of a game in which countries (firms) choose quantities or prices simultaneously and independently. That is, Bertrand equilibrium and Cournot equilibrium can be thought of as the maximizing outcome of countries (firms) acting independently at a single instant. This very seldom is a realistic story, but it is consistent and grounded in maximization. The conjectural variations story, on the other hand, involves arguments of the form " if the U.S. increases its wheat exports by one unit, then EU will match half of the US's increase...." Therefore, it is a story that must involve a sequence of decisions taken over time. But if this is accommodated by the model, then it is important to make the dynamics explicit in the model. Trying to include the dynamic interaction of countries (firms) into a single-period (static) equilibrium concept leads to a situation in which one does not know what is supposed to be happening, and so the grounding in maximization is lost (Helpman and Krugman).

The second problem, stated by Helpman and Krugman, is that because the conjectural variation parameter lacks any grounding in maximizing behavior, exercises in comparative statics become questionable. Suppose that we have fitted our conjectural variations model to international wheat markets with the aid of an estimated value of $\nu$ that corresponds to neither the Cournot nor the Bertrand case. Now we try to ask how the outcome would have been different in the presence of some government policy- say an EEP program. What should be assumed about conjectural variations in the new equilibrium? Usually, it is assumed that $\nu$ remains unchanged, even though there is no reason to presume that this should be the case. Actually, Paarlberg and Abbott (1986) have shown that conjectural variations do not stay constant over time.

In the case of many empirical conjectural variation models, due to insufficient data, a calibration technique is used to do strategic trade policy analysis. Calibration methods start with a model containing general parameters that are to be replaced with specific values. In contrast to using multiple observations to estimate these parameter values econometrically, most parameter values are taken from external sources. These external sources may include previous econometric work, engineering studies, and the analyst's judgment. Then the remaining parameters, not drawn from external sources, are calibrated in a manner to reproduce some base period data. (For more about calibration/simulation models see Sheldon (1992) and Brander (1995).)

Two well known examples on this type of conjectural variation models are Dixit (1988) and Baldwin and Krugman (1988). Dixit uses his calibrated version of the conjectural variations model to carry out some strategic trade policy experiments on the U.S. automobile industry. Baldwin and Krugman constructed a calibrated oligopoly model of the 16K RAM market to examine the effects of Japanese home market protection on market outcomes and welfare.

### 3.3.1. Agricultural Trade Models

Over the past 30 years there has been considerable interest in whether or not the world grain markets operate competitively, and if not, what type of market structure best describes the situation. Imperfect competition was introduced into agricultural trade modeling for the first time by McCalla (1966). In his theoretical analysis of price formation, the market structure of the wheat market was a cooperative duopoly comprised of Canada and the United States, with a fringe of competitive followers. Canada was postulated to be the price leader. Taplin (1969) applied the kinked demand curve approach to the same duopolistic wheat market structure. Nine years later Alouze et al. (1978) extended the theoretical model structure to a triopoly model with Australia added as a third member with market power. They also identified Canada as being the price leader.

One problem with these models is that they are essentially theoretical models. Therefore, no empirical numerical support is provided. Also, the use of the kinked demand curve approach has been criticized because it tries to model dynamic price competition in a static framework (for more criticism of the kinked demand curve story see Tirole (1988)).

Generally, more acceptable inclusion of strategic interaction into the model requires the introduction of game theoretic analysis. The first attempts to do this in agricultural trade model were made by Karp and McCalla (1983), Paarlberg and Abbott (1986, 1987), Kolstad and Burris (1986), and Hillberg (1988). The last three were static models for world wheat trade, and the first one was a discrete-time dynamic game (difference game) applied to the world corn market.

Kolstad and Burris built a spatial equilibrium model in which producing country governments are Cournot quantity competitors who maximize profits and have the ability to price discriminate between domestic and foreign sales. For 1972-73 trade flows, they examine assumptions of 1) a United States-Canada duopoly, 2) a U.S.-Canada-Australia triopoly, 3) a Japan-EEC duopsony, and 4) perfect competition. They find that the U.S.-Canadian duopoly was the most appropriate market structure with which to characterize the international wheat market in the early 1970s.

Paarlberg and Abbott argued that the policy formation process is responsive to lobbying by domestic special interest groups and that the influences of all groups may not be equal. They show that special interest groups' differing influences can account for differing responses among countries to a change in the international markets. By recognizing that policies are designed to redistribute income among domestic political interest groups and among nations, policy formation can be made endogenous to all countries. Paarlberg and Abbott used a conjectural variation model in which conjectures were endogenous.

Other examples of static conjectural variation models for the international grain market are Thursby (1988), and Thursby and Thursby (1990). Thursby and Thursby (1990) used a calibration model to assess the competitive behavior of the Canadian Marketing Board and U.S. wheat exporting firms in their trade with Japan. Yamazaki et al. (1992) followed a procedure similar to Thursby and Thursby to examine the structure of the world soybean market. McCorriston and Sheldon (1991) developed a model to evaluate policy actions in the U.K. fertilizer market.

Hillberg (1988) constructed and integrated Nash bargaining game models with a quarterly spatial price equilibrium model to determine the Export Enhancement Program's impact on the world wheat market. The first bargaining model characterized the determination of EEP sales to a targeted country as a negotiation between the Commodity Credit Corporation and the targeted country over an EEP bonus. In the second bargaining model the exporting firms and targeted country negotiated over the EEP price level while simultaneously the exporting firm and the CCC negotiated over the level of the EEP bonus.

Karp and McCalla (1983) were the first to introduce a dynamic game model for agricultural trade. They built a discrete-time dynamic game model for the world corn market in which both the importing and exporting nations have potential market power. The information structure of each player was assumed to be a feedback information pattern. The functional forms in the game were linear-quadratic, meaning that players' (countries') objective function were quadratic in the state and control variables, and state equations were linear in these variables. They studied strategic behavior of the United States (exporter), the European Community (as an importer) and Japan (importer) in the corn market.

Since then, few dynamic, game theoretic models of agricultural trade have been built. The main contributors of these models are Karp and Perloff (1989, 1993a-b). All the Karp-Perloff models are used to identify, estimate, and test the competitiveness of these markets. By using linear-quadratic dynamic oligopoly models they study two markets: rice and coffee export markets. Deodhar and Sheldon (1995) apply the same model structure to study market behavior in the banana export markets. None of these models try to do any policy analysis, even though Karp and McCalla (1983) state that difference games could be useful for policy analysis. One of the reasons for this is that dynamic game models have a tendency to become analytically intractable very easily.

The first attempt, since Karp and McCalla (1983), to do trade policy analysis in a dynamic game setting was done by McNally (1993). In contrast to Karp and McCalla, she makes her model more realistic by adding a stage in which exporting firms compete in prices in addition to governments setting export subsidies or export taxes. Then she uses the model to carry out strategic trade policy analysis in the international wheat market. In her dynamic simulations she confirmed the results from the familiar static models, i.e., optimal export policy (a subsidy or tax) depends on the order of play. In the *ex ante* game, where governments are the first-movers, choosing an export policy level before firms negotiate a price, the optimal export policy is a tax. Alternatively, in the *ex post* game firms are the first-movers, negotiating a price before governments choose an export subsidy. In this game an export subsidy becomes the optimal policy for governments, because the firms negotiate prices to provoke a subsidy instead of a tax. However, no econometric estimations were used to find values for import demand function parameters. Rather, these values were derived from trade elasticities of previous studies of the world wheat market.

## 3.4. Politics and Trade Policy

A large political economy literature has examined possible explanations for prevailing trade policies. In this research, efficiency considerations have not played center stage. Many policies, such as export subsidies and voluntary export restraints, impose large burdens on society. Therefore, researchers looked for objectives of policy makers other than overall efficiency in order to explain them. The political economy literature emphasizes distributional considerations.

It views trade policy as a device for income transfers to preferred interest groups in society. Furthermore, it explains the desire of a policy maker to engage in this sort of costly transfer by means of political arguments in the policy maker's objective function (see Helpman (1995) for a review).

Political economy explanations of trade policies are important. The political economy literature helps one to understand the structure of protection as well as major public policy debates. It would be impossible to understand such debates while ignoring political aspects. Quite often countries design their trade policies in a way that yields to pressure from special interest groups, and trade negotiations in the international arena respond similarly. It is also apparent from casual observation of agricultural trade policy that governments respond to the income concerns of certain domestic groups, especially agricultural producers (and producers generally).

Empirical work in this area has been done by Sarris and Freebairn (1983), Paarlberg and Abbott (1986), Oehmke and Yao (1990), Johnson et al. (1993), and Kennedy et al. (1996), for example. All of these studies used the policy preference function (PPF) (also called as criterion function) approach suggested by Rausser et al. (1982). In this approach the policymaker's objective function is given as the weighted sum of domestic special interest groups' welfares. Different numbers of special interest groups were used in these studies but they all concluded that the weight on wheat (grain) producers exceeds one.

Alston et al. (1993) used a political economy approach to show that export subsidies may be the least-cost means of making income transfers to producers in a world in which general taxation measures involve an excess burden. Furthermore, their results showed that, everything else constant, changes in the marginal excess burden of government revenues[8] ($\mu$) did not have much impact on the optimal policy. The importance of $\mu$ arises from the fact that it is not zero.

Note that there is an overlap with imperfect competition studies mentioned earlier. When strong special interest groups exist in the market, they can, by lobbying, make the government utilize its market power in the market such that it favors these special interest groups. The existence of export subsidies, for example, illustrates the producer bias in agricultural policy setting.

This dissertation has a political economy aspect, as well. In the empirical model each government wishes to maximize domestic welfare which equals revenues from wheat exports less the cost of net transfers to the exporting firm. This objective function is consistent with Brander-Spencer framework in the sense that its weight on domestic consumer surplus is set to zero. However, we

[8] Marginal excess burden here means the marginal welfare cost of raising extra revenue from an existing distorting tax.

depart from the usual Brander-Spencer objective function in two ways. First, we attach to the value of subsidy payments a weight $\mu$ which may exceed unity. This reflects the deadweight cost of raising taxes in the economy to finance export subsidy expenditures. Among others this approach has been used by Gruenspecht (1988), McNally (1993), Neary (1995) and Brainard and Martimort (1996) in their strategic trade policy analysis. Second, export revenues replace the usual exporting firm's profits as a term in the objective function. After studying the behavior of the EU and U.S. in the international wheat market and their criteria for assigning export subsidies, we think that replacing profits with export revenues in a government's objective function makes the model more consistent with what we observe in the real world (see Chapter II).

## 3.5. Some Background on Switching Cost Theory

Empirical games were briefly reviewed in the earlier section because we need to use a game-theoretical model to capture strategic interaction in the world wheat market. As a result, the fourth problematic assumption mentioned by Paarlberg (1984) can be relaxed. Recall also from Chapter II that an importing country cannot switch freely between suppliers when making purchase decisions. It faces costs of switching. These switching costs imply that current decisions have an effect on the future. Therefore, a dynamic modeling approach needs to be applied. The second assumption listed at the beginning of the chapter is relaxed. This section highlights some of the effects that the introduction of switching costs has on the model.

In many markets buyers who have previously purchased from one seller incur costs when switching from that seller to one of its competitors. Therefore, these switching costs give each buyer a strong incentive to continue buying from the firm from which it has previously purchased, even if other firms are selling functionally identical products. The switching costs literature also sheds light on why managers often seem concerned with market share in addition to short run profits. Consumer switching costs give firms a degree of monopoly power over their repeat-purchasers, so a firm's current market share is an important determinant of its future profits. Given the pervasiveness of such costs, it is not surprising that there has been considerable effort to model and analyze this aspect of markets (von Weizäcker 1984, Klemperer 1987a-c, 1988, 1989, 1992, Farrel and Shapiro 1988, Beggs and Klemperer 1992, Padilla 1992a-b, and Sapir and Sekkat 1995). For a comprehensive review of the switching cost literature see Klemperer (1995).

Klemperer (1987a) points out three sources of switching costs. The first is transaction costs. Two banks may offer identical checking accounts, but there are some transaction costs in closing an account with one bank and opening another with a competitor. In the international wheat trade setting, one transaction cost is the cost of negotiating a contract or agreement with a supplier. An importer's contracting costs with a new exporter are higher than contracting costs with a prior exporter. The second is learning costs. The learning required to use one brand may not be transferable to other brands of the same product, even though all brands are functionally identical. For example, a number of computer manufacturers may make machines that are functionally identical. If a consumer has learned to use one firm's product line, and has invested in the appropriate software, he has a strong incentive to continue to buy computers from the same firm, and to buy software compatible with them. Also, there is more risk involved when buying from a new, unfamiliar supplier than when buying from an old familiar supplier. For example, in international wheat trade there is less uncertainty about variables like the quality of the wheat or the time that it takes to ship the wheat, when dealing with a familiar supplier. The third category is artificial switching costs. These costs arise as results of firms' actions. Examples of such actions include repeat-purchase coupons and frequent-flyer programs that reward customers for repeated travel on the same airline, and so penalize brand-switchers.

A very simple two-period duopoly model is used below to illustrate the effects of buyer's switching costs. The presentation follows Klemperer (1995).

### 3.5.1. A Two-period Switching Cost Model

When market share is valuable, there will be competition for it. In this two-period model a (representative) consumer incurs no switching costs in the first period, but develops switching costs as a result of her first-period purchases. Therefore, firms have some monopoly power in the second (final) period.

The general method for solving a two period model is first to solve for firms' optimal second-period behavior, and hence firms' second-period profits, for any given first-period sales or market shares (since first-period sales determine the size of the switching costs the representative consumer faces when planning to buy more from any other firm in the second period). That is, given the sizes of the switching costs and the nature of second-period competition, firm $i$'s second-period profits, $\pi_2^i$, are determined as a function of its first-period sales (or market share), $q_1^i$.

In the second period the representative consumer has a switching cost $s\left(q_1^A\right)$ when buying more than previously from the firm B, and a switching cost $s\left(q_1^B\right)$ when buying more than before from the firm A[9]. Thus, in this second period "mature market" consumer's switching costs have already been built up, and the

[9] Note that $s(q_1^i)$ is assumed to be a increasing function of output (or market share), $q_1^i$ because the more consumers buy from firm $i$ the more dependent they become on firm $i$ as a supplier.

firm who had the largest market share in the first period enjoys an advantage over the other firm due to the presence of switching costs. This is because the larger market share implies larger costs of switching to the other supplier. This result, that switching costs built up in the past generate current profits that depend on firms' previous market share, is very general.

The above described the second period of the a two-period market in which second-period switching costs are created by first-period sales. Now we consider the first period when consumers are not attached to any particular firm. With switching costs in the second period, firms will compete more aggressively in the first period, because increased sales increase market share and so increase second period profits.

In period 1, each firm $i$ chooses its first-period strategic variable to maximize its total discounted profits

$$V^i = \pi_1^i + \delta\pi_2^i\left(q_1^i\right) \tag{3.14}$$

taking its rival's first-period strategic variable as given. Here $\pi_1^i$ are the firm's first-period profits, and $\pi_2^i$ are the firm's second-period profits, which can be written as a function of the firm's first-period sales or market share $q_1^i$, and are discounted by a factor $\delta$.

For simplicity, it is assumed that firms choose prices in period one.[10] Maximizing with respect to first-period price, firm $i$'s first-order condition for equilibrium is

$$0 = \frac{\partial\pi_1^i}{\partial p_1^i} + \delta\frac{\partial\pi_2^i}{\partial q_1^i}\frac{\partial q_1^i}{\partial p_1^i}. \tag{3.15}$$

Now provided the firm's first-period sales (or market share) decreases in its first-period price, $\partial q_1^i/\partial p_1^i < 0$, and the firm's second-period profits are increasing in its first-period sales (or market share), $\partial\pi_2^i/\partial q_1^i > 0$, then $\partial\pi_1^i/\partial p_1^i > 0$. That is, $p_1^i$ is lower than the price at which $\partial\pi_1^i/\partial p_1^i = 0$[11]. This says that firms' first-period prices are lower than if they were simply maximizing first-period profits, because they are competing for market share that will be valuable to them in the future.

[10] Effects will be similar if the strategic variable were something other than price.

[11] It is assumed that $\pi_1^i$ is quasiconcave in $p_1^i$ and that the first-order condition specifies an equilibrium.

Three caveats should be noted regarding the discussion above. First, it is conceivable that greater sales (or market share) may hurt a firm if, by reducing its competitor's market share, it makes the competitor sufficiently more aggressive. In this case $\partial\pi_2^i / \partial q_1^i < 0$, so firms compete less fiercely than they otherwise would in the first period, in order to avoid gaining market share or avoid facing more aggressive competitors in the future.

Second, the presence of switching costs in the second period means that the consumer's first-period purchase decisions depend on their expectations of second-period prices. Thus, the structure of first-period demand is also affected and is typically made less elastic by the presence of switching costs in the future. Thus, although equation (3.15) implies that firms charge lower first-period prices than if they ignored the effect of switching costs on their second-period profits, it is possible that first-period prices may still be higher than in an otherwise identical market without second-period switching costs (Klemperer 1987b).

Finally, the focus above has been on prices net of switching costs. If consumers must pay a start-up cost in the first period when they buy from any firm, then the real cost (price plus any start-up or switching cost) paid by consumers may fall over time.

Switching costs are intuitively appealing, and they exist to some degree in many markets. Chapter II provided some suggestive evidence on the existence of switching costs in international wheat trade. Such factors as guaranteed credit programs by exporting countries and government relationships were considered as two of the major factors effecting an importing country's decisions on to what extent to import wheat from each source. Both of these factors lock the importing country in to each supplier to some degree. Since it seems likely that switching costs exist in international wheat trade they need to be taken into account in our modeling framework, as well. Incorporation of these costs makes a dynamic modeling approach necessary.

## 3.6. Conclusions

Traditional agricultural trade models were reviewed and it was recognized that they required several problematic assumptions. Chapter II described the international wheat market as a market where strategic interactions between the European Union and the United States, as well as between large exporting firms, are likely to exist. Game-theoretic methods, which allow us to take into account this aspect, have been used in the more recent agricultural trade modeling literature. The majority of these studies used static models in their analysis, however.

Static models can provide useful summary statistics concerning outcomes of oligopolistic interaction, but they are really only a first step in the economist's attempt to understand the strategic behavior that appears in international wheat trade. In practice, firms and governments are interacting repeatedly. With repeated interaction, governments must take into consideration not only the possible increase in current welfare but also the possibility of an export subsidy war and long-run losses when deciding whether to subsidize exports more now. Thus, a dynamic approach seems appropriate, but only a limited number of dynamic studies exist.

One way to make strategic trade policy analysis dynamic is by introduction of switching costs into the model framework. This is an intuitively appealing approach and Chapter II showed that switching costs are likely to exist in the international wheat market. So far, this approach has not been employed in the agricultural trade literature.

# CHAPTER IV

## EXPORT SUBSIDIES IN INTERNATIONAL WHEAT TRADE WITH SWITCHING COSTS – THEORETICAL FRAMEWORK

The international wheat market is characterized by two main departures from perfect competition. First, large exporters have market power, and second, importing countries do not base their purchasing decisions solely on the price of the product. Other factors affecting importers' decisions include the quality of wheat, which varies between suppliers, and costs of switching from one exporter to another. These switching costs might exist for several reasons. An importer incurs costs negotiating a contract or agreement with a supplier, and these transaction costs with a new exporter may be higher than with an existing exporter. Another category is learning costs. There is more risk involved when buying from a new, unfamiliar source than when buying from an existing supplier. There also might exist political costs of switching between exporters. One would expect products supplied by political allies to be viewed differently from others.[1]

Since there is imperfect competition between exporters, the international wheat market can be modeled as a game in which exporters interact in a noncooperative manner. For example, the failure of GATT to eliminate export subsidies can be seen as a result of countries' making decisions based on their perceived self-interest, and not collaborating, which could have led to improved welfare of the world. A Prisoner's Dilemma- type situation occurs in which each country is worse off because all countries subsidize their exports heavily (Kennedy et al. (1994)).

In Chapter III, traditional agricultural trade models were reviewed, and the conclusion was that none of the models was able to capture all these characteristics of the international wheat market satisfactorily. When modeling this kind of market the proper thing to do is to use noncooperative game theory as a tool, because it allows us to incorporate strategic interaction between large exporters in the analysis. In addition, it is important (and possible) to explicitly capture institutional factors (such as switching costs) affecting importers' purchasing decisions.

The task of this chapter is to examine export policy using a differentiated product model of oligopolistic competition with switching costs. A switching cost model captures the idea that importing countries who have previously purchased from one exporter incur costs when switching from that exporter to one of its competitors. Therefore, these possible switching costs give each

[1] For more on different categories of switching costs see Klemperer (1995).

importer an incentive to continue buying from the supplier from which it has previously purchased, even if other exporting countries are selling functionally identical products.

This chapter starts by presenting a two-period strategic trade policy model in which the introduction of switching costs into the economic model follows Sapir and Sekkat (1995). To (1994) applies a switching cost model in an international trade framework. However, he employs Klemperer's (1987b) alternative method of introducing switching costs into the model. The motivation for choosing Sapir and Sekkat's approach instead of Klemperer's is that it is the more appropriate form for empirical implementation in the case of a parastatal grain marketing board as the buyer.

Differences between these two approaches are elaborated later in this chapter when the importing country's behavior is derived. The differences between our model and To's are: (i) our model explicitly includes switching costs; (ii) To's implementation of switching costs is a simplified version of Klemperer's whereas our model employs Sapir and Sekkat's approach; (iii) in our model firms incur nonzero marginal costs; (iv) in our model each government's objective is defined as export revenues less export subsidy expenditures instead of domestic firm's profits minus export subsidy expenditures; (v) our model assumes naive instead of rational consumer expectations; and (vi) in contrast to To's model, which assumes Hotelling consumer demand, we derive a linear demand structure from a quasilinear utility function (Sing and Vives 1984).

In the first section of this chapter a two-period model of oligopolistic competition with differentiated products and switching costs is constructed. The model is explained in detail to highlight the effects that the introduction of switching cost has on the behavior of exporting countries (both firms and governments).

A two-period model might be appropriate where there is a natural beginning to the market and we wish to distinguish "early periods" from "later periods". However, in reality we very seldom have a first period in which no switching costs emerge. Furthermore, such a model does not tell us what to expect from competition over many periods. Will exporting countries' temptation to exploit their current share of the market lead to higher prices and lower subsidies than in the absence of switching costs, or will exporting countries desire to achieve larger market share lead to lower price and higher export subsidies? Thus, the two-period models may not be the most satisfactory for analyzing, among other things, the effects of policy shocks which vary over time (e.g., restrictions on export subsidies by GATT) or other shocks. Therefore, the second section of this chapter extends the two-period model of the first section into a more general finite-horizon multi-period model of competition in a market with switching costs. Other generalizations of this section include more general (though linear) import demand functions, asymmetric marginal costs and the introduction of opportunity costs of public funds to capture the fact that raising tax revenues to cover export subsidy expenditures incurs administrative costs or creates distortions in other sectors of the economy.

The organization of this chapter is as follows. Section 2 presents the two-period international wheat trade model with switching costs. That section analyzes how the second-period equilibrium depends on first-period market shares. Knowing this second-period equilibrium allows us to solve for the first-period equilibrium, and hence the outcome of the whole game. Section 3 then presents a more general multiperiod model which in the later chapters will be applied to empirically analyze international wheat trade.

## 4.1. A Two-period International Wheat Trade Model With Switching Cost

This model will be limited to two exporters (e.g., United States and the European Union) and one importer (e.g., Morocco). In each exporting country there are two players: the government and the aggregate firm. In each period (*t=1,2*), the governments simultaneously choose export subsidies (taxes if negative), $S_t^i$, to maximize domestic welfare. After that, firms in both exporting countries simultaneously choose prices, $P_t^i$, to maximize profits. We look for a symmetric subgame-perfect equilibrium.

First, we need to derive the importing country's behavior. In international wheat trade many importing country governments exclusively handle their foreign trade of wheat through parastatal agencies. This parastatal agency also decides how much of the wheat to buy from each origin. Therefore, this agency of the importing country can be seen as a single representative consumer. Although the parastatal agency handles an importing country's foreign trade of wheat, it is assumed to be small relative to the total international wheat market. Therefore, it does not have market power in the international wheat market[2].

In the first period, the importing country's demand for wheat from exporting country $i$ is described by an import demand function $M_1^i = M_1^i\left(P_1^i, P_1^k\right)$, where $i$, $k$ = *US, EU*, and $i \neq k$. These import demands are derived from the importing country's utility maximization problem.

Following Singh and Vives (1984) the aggregate utility function is assumed to be quasilinear. Therefore the problem of preference maximization can be written as

$$u_1\left(Q_0, M_1^i, M_1^k\right) = Q_0 + U_1\left(M_1^i, M_1^k\right) \tag{4.1}$$

[2] This assumption on market power is appropriate for most of the importing countries (e.g., Morocco), but possibly not for all (e.g., USSR in early 1980s).

$$\text{such that } Q_0 + \left(P_1^i + \bar{\tau}\right)M_1^i + \left(P_1^k + \bar{\tau}\right)M_1^k = income,$$

where $Q_0$ is aggregate consumption of a numeraire good, $\bar{\tau}$ equals all other costs, excluding the price charged by the exporter attached with the purchase of the product (i.e., transaction costs, learning costs, etc.), and $U_1$ is a quadratic subutility function for the wheat sector defined by:

$$U_1\left(M_1^i, M_1^k\right) = \alpha\left(M_1^i + M_1^k\right) - \tfrac{1}{2}\left(\beta\left(M_1^i\right)^2 + \beta\left(M_1^k\right)^2 + 2\gamma M_1^i M_1^k\right). \tag{4.2}$$

Then the import demand function for each exporting country's wheat can be generated by maximizing the representative consumer's (parastatal agency's) consumer surplus: $CS_1 = U_1\left(M_1^i, M_1^k\right) - \left(P_1^i + \bar{\tau}\right)M_1^i - \left(P_1^k + \bar{\tau}\right)M_1^k$, where the last two terms are the costs for the parastatal agency of acquiring imports $M_t^i$ and $M_t^k$. The quadratic subutility function implies that all import demand functions are linear in prices[3].

First-order conditions yield inverse demand functions of the form

$$P_1^i = \alpha - \beta M_1^i - \gamma M_1^k - \bar{\tau} \tag{4.3}$$

$$P_1^k = \alpha - \beta M_1^k - \gamma M_1^i - \bar{\tau}, \tag{4.4}$$

where all parameters are positive[4] and $\beta^2 - \gamma^2 > 0$. Finally, the corresponding direct import demand functions used in our analysis are

$$M_1^i = a - b\left(P_1^i + \bar{\tau}\right) + e\left(P_1^k + \bar{\tau}\right) \tag{4.5}$$

$$M_1^k = a - b\left(P_1^k + \bar{\tau}\right) + e\left(P_1^i + \bar{\tau}\right), \tag{4.6}$$

where $a = \dfrac{\alpha}{\beta + \gamma}$, $b = \dfrac{\beta}{\beta^2 - \gamma^2}$, $e = \dfrac{\gamma}{\beta^2 - \gamma^2}$ and $b > e$.

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[3] Note that here the subutility function is defined so that it yields symmetric inverse demand functions, i.e., $\alpha^i = \alpha^k = \alpha$ and $\beta^i = \beta^k = \beta$. In the multiperiod model this symmetry assumption is relaxed.

[4] The goods are substitutes, independent, or complements according to whether $\gamma>0$, $\gamma=0$, or $\gamma<0$, respectively. Wheats from different sources are generally substitutes, therefore $\gamma>0$ is expected.

In the second period, switching costs have an effect on the importing country's behavior. This implies that costs for the parastatal agency of acquiring imports $M_2^i$ and $M_2^k$ are defined differently. Now, all the other costs, $\tau$, include costs which are diminished for the repeat-purchasers of the product. Therefore, the more the parastatal agency imports exporting country $i$'s wheat in the first period, the smaller are all the other costs due to buying the same exporter's product in the second period. Thus, dynamics are introduced into the model by assuming that all other costs for buying good $i$ are a decreasing function of previous purchases of good $i$, and can be stated as

(4.7) $$\tau_2^i = \bar{\tau} - \eta M_1^i \qquad i = US, EU.$$

Switching costs are therefore captured by the term $\eta M_1^i$, where $\eta$ is a positive parameter. It is assumed that $\eta$ ,"the marginal switching cost", is small relative to parameters $b$ and $e$.[5] Larger values for $\eta$ or $M_1^i$ make costs of buying again from exporter $i$ smaller, so the importing country is less willing to switch to exporter $k$'s wheat. Thus, the cost of importing quantities $M_2^i$ and $M_2^k$ in the second period is defined by

(4.8) $$C_2\left(M_2^i, M_2^k\right) = \left(P_2^i + \tau_2^i\right)M_2^i + \left(P_2^k + \tau_2^k\right)M_1^k,$$

where $\tau_2^i$ and $\tau_2^k$ are given by equation (4.7).[6]

In each period each firm incurs marginal cost $c$ per unit and no fixed costs. It noncooperatively chooses a price to maximize discounted profits. The governments of the exporting countries maximize discounted welfare, measured as the

[5] This assumption is supported by our econometric estimation in Chapter V.

[6] An alternative approach to introducing switching costs into the model would be to apply the dynamic framework presented by Klemperer (1987b). In his spatial location model of product differentiation Klemperer divides second period consumers into three different fractions: new consumers, "switchers", and locked-in consumers. New consumers replace the first period consumers who left the market after the first period, and they have no ties to any particular exporting country. "Switchers" are a fraction of consumers that face the costs of switching, but they also can have changing tastes for underlying product characteristics which at least for some consumer's can outweigh their switching costs. The remaining fraction is comprised of the fully locked-in consumers for whom it is too costly to switch to another supplier (see Klemperer 1987b). The model's theoretical findings are similar to the model used in this study and some additional interesting comparative statics can be drawn. However, that approach is not applied here because it is less appropriate for empirical implementation to the case of a parastatal grain marketing board.

sum of discounted net export revenue. Firms and governments both have the same discount factor $\delta$.

The model is a finite four-stage game, where the stages in order of action are the first period simultaneous-move game of governments, then the first period simultaneous-move game of firms, then the second period simultaneous-move game of governments, and finally the second period simultaneous-move game of firms.

Because the equilibrium concept is subgame perfection, analysis of the model begins with the last stage. The strategies in the last stage must specify a Nash equilibrium of the one-shot price game of firms given any history. For each such assignment of Nash equilibria to the last (fourth) stage, the third-stage export subsidy game of governments is solved to form a two-stage Nash equilibrium for any history. Similarly, using backward induction the other two stages are solved to find a subgame-perfect equilibrium for the overall model. Thus, to solve our two-period model we start by solving for firms' (who are the last movers in the game) optimal second period behavior and hence firms' second-period profits, for any given second-period export subsidies and for any given first-period export quantities.

### 4.1.1. The Second Period

First we derive the import demand functions for each exporting country's wheat in the second period. By maximizing the representative consumer's surplus, $CS_2 = U_2\left(M_2^i, M_2^k\right) - C_2\left(M_2^i, M_2^k\right)$, with respect to $M_2^i$ and $M_2^k$ we achieve the demand system

$$M_2^i = a - b\left(P_2^i + \tau_2^i\right) + e\left(P_2^k + \tau_2^k\right) \tag{4.9}$$

$$M_2^k = a - b\left(P_2^k + \tau_2^k\right) + e\left(P_2^i + \tau_2^i\right), \tag{4.10}$$

where all the parameters are positive and $b > e > 0$ [7]. The subgame-perfect equilibrium can be now derived.

[7] Provided that quantities are positive, that is in the region $\Lambda = \left\{\mathbf{P} \in \Re_+^2 : a - b\left(P_2^i + \tau_2^i\right) + e\left(P_2^k + \tau_2^k\right) > 0,\ a - b\left(P_2^k + \tau_2^k\right) + e\left(P_2^i + \tau_2^i\right) > 0\right\}$.

#### 4.1.1.1. The Exporting Firm's Problem

Firms choose their prices to maximize second-period profits given the second-period subsidy levels chosen by the governments and given firms' imports from the first period. Firm $i$'s second-period profits are

$$\pi_2^i = \left(P_2^i + S_2^i - c\right)M_2^i . \tag{4.11}$$

Substituting (4.9) into (4.11) and maximizing with respect to $P_2^i$ we get the first-order condition for profit maximization.[8] Using this we can solve for the best-response function of firm $i$

$$P_2^i\left(P_2^k\right) = \frac{1}{2}\left\{\frac{a}{b} + c - S_2^i - \tau_2^i + \frac{e}{b}\left(P_2^k + \tau_2^k\right)\right\}. \tag{4.12}$$

The intersection of best-response functions for firms $i$ and $k$ gives second period prices as a function of the second period subsidies and first period imports:

$$\begin{aligned} P_2^i = \frac{1}{\left(4b^2 - e^2\right)}\Big[&(2b+e)\left(bc + a - (b-e)\bar{\tau}\right) - b\left(2bS_2^i + eS_2^k\right) \\ &+ \left(2b^2 - e^2\right)\eta M_1^i - be\eta M_1^k\Big]. \end{aligned} \tag{4.13}$$

A simple comparative statics exercise shows the standard result that country $i$'s wheat price paid by the importer decreases as country $i$ and/or country $k$ increases its export subsidy. It can also be seen that an exporting country's price is more strongly affected by its own export subsidy than its rival's subsidy.

A more interesting comparative statics result is that country $i$'s second period price increases as its first-period market share increases.[9] Therefore, firms may have an incentive to fight more fiercely over first period market share. Hence, market shares matter. Furthermore, the comparative statics show that the second period price either increases or decreases when switching costs increase, depending on the firm's market share captured in the first period. A firm with a

[8] The second-order condition is satisfied, since -2b<0.

[9] Actually, country $i$'s second-period price increases as its first-period exports increase. Therefore, it is assumed in the text that larger exports always imply larger market share.

large first period market share $\left(\sigma_1^i > \frac{be}{(2b-e)(b+e)}\right)$ is relatively more interested in exploiting its market share by charging a higher price and less interested in attracting an even larger share of the market than is its smaller rival, who charges a lower price to win back market share. (In addition, when $\eta = 0$ this model is identical to a model without switching costs.) These results are similar to Klemperer (1987b).

By substituting equation (4.13) into (4.9) we get the second-period wheat exports of country $i$ as a function of export subsidies:

$$M_2^i = \frac{b}{(4b^2 - e^2)}\left[(2b+e)(a-(b-e)(c+\bar{\tau})) + (2b^2 - e^2)(S_2^i + \eta M_1^i) - be(S_2^k + \eta M_1^k)\right], \tag{4.14}$$

and substituting (4.13) and (4.14) into (4.11) yields firm $i$'s second-period profits:

$$\pi_2^i = \frac{b}{(4b^2 - e^2)^2}\left[(2b+e)(a-(b-e)(c+\bar{\tau})) + (2b^2 - e^2)(S_2^i + \eta M_1^i) - be(S_2^k + \eta M_1^k)\right]^2. \tag{4.15}$$

We now move to the government's optimization problem in period two.

### 4.1.1.2. The Exporting Government's Problem

Government maximizes the country's second-period welfare by choosing its export subsidy given first period exports and expected firm behavior. Domestic welfare is measured here as total export revenue minus expenditures on export subsidies[10]:

$$W_2^i = (P_2^i + S_2^i)M_2^i - S_2^i M_2^i = P_2^i M_2^i. \tag{4.16}$$

[10] It is implicitly assumed here that the government places equal weight on the home firm's export revenue and government subsidy expenditures in evaluating social welfare. Following Gruenspecht (1988), Neary (1994) and Brainard and Martimort (1996) we relax this assumption in the multiperiod model by introducing the opportunity cost of government funds into the model.

This welfare function is similar to one used in standard third-market models (Brander and Spencer 1985).[11] However, we depart from the usual Brander-Spencer objective function here by replacing the usual exporting firm's profits as a first term in the objective function with export revenues. From a political economy literature perspective we can view this objective function as a policy preference function in which exporting firms' revenues and budgetary expenses of export subsidies are equally weighted and zero weight is given to consumers as a special interest group. After studying the behavior of the EU and U.S. in the international wheat market and their criteria for giving out export subsidies, we think that replacing profits with export revenues in a government's objective function makes the model more consistent with what we observe in the real world (see Chapter II).

Substituting (4.13) and (4.14) into (4.16) and taking the first derivative with respect to $S_2^i$ yields a first-order condition for maximum welfare. The first-order condition is then solved for $S_2^i$ to get country $i$'s best-response function as:

$$S_2^i\left(S_2^k\right)=\frac{1}{4b^2\left(2b^2-e^2\right)}\Big[b(2b+e)\left(4b^2-e^2-2be\right)c-e^2(2b+e)\left(a-(b-e)\overline{\tau}\right)$$
$$(4.17)\qquad +e^2\left(be\left(S_2^k+\eta M_1^k\right)-\left(2b^2-e^2\right)\eta M_1^i\right)\Big].$$

Second-period equilibrium export subsidies are given by the intersection of the two best-response functions:

$$S_2^i=c-\frac{e^2}{b\left(4b^2-e^2-2be\right)}\left(a-(b-e)\overline{\tau}\right)$$
$$(4.18)\qquad -\frac{e^2\left[b\left(4b^2-3e^2\right)\eta M_1^i-e\left(2b^2-e^2\right)\eta M_1^k\right]}{b\left[\left(4b^2-e^2\right)^2-(2be)^2\right]}.$$

Substituting this into (4.13), (4.14) and (4.15) allows second-period prices, exports and profits to be expressed as a function of first-period exports:

$$(4.19)\qquad P_2^i=\frac{2b}{\left(4b^2-e^2-2be\right)}\left[a-(b-e)\overline{\tau}+\frac{b\left(4b^2-3e^2\right)\eta M_1^i-e\left(2b^2-e^2\right)\eta M_1^k}{\left(4b^2-e^2+2be\right)}\right],$$

11 In a standard third-market model one firm from a domestic country and one firm from a foreign country compete only in a third market.

$$(4.20)\quad M_2^i = \frac{\left(2b^2 - e^2\right)}{\left(4b^2 - e^2 - 2be\right)}\left[a - (b-e)\overline{\tau} + \frac{b\left(4b^2 - 3e^2\right)\eta M_1^i - e\left(2b^2 - e^2\right)\eta M_1^k}{\left(4b^2 - e^2 + 2be\right)}\right],$$

$$(4.21)\quad \pi_2^i = \frac{\left(2b^2 - e^2\right)^2}{b\left(4b^2 - e^2 - 2be\right)^2}\left[a - (b-e)\overline{\tau} + \frac{b\left(4b^2 - 3e^2\right)\eta M_1^i - e\left(2b^2 - e^2\right)\eta M_1^k}{\left(4b^2 - e^2 + 2be\right)}\right]^2.$$

Comparative statics shows that prices and exports volumes as well as profits are increasing, and export subsidies are decreasing, in first period market share.

From equation (4.18) it can be seen that the sign of $S_2^i$ is ambiguous and cannot be determined without empirically analyzing the market. This differs from To's (1994) proposition, "in the second period both countries set export taxes", because the government's objective function in his model is different from the one used here. In To's model government maximizes domestic firm's profit level plus tax revenues. As we can see from equation (4.18) this generalization is not possible in our model when firms have nonzero marginal costs, $c > 0$. However, it can be stated that, the smaller the wheat sector's marginal costs are, the more likely it is that an export tax ($S_2^i < 0$) will be the optimal policy. On the other hand if a country's wheat sector operates inefficiently (i.e., the firm's marginal costs are high) then a subsidy might become optimal (e.g., in EU). The sign of $S_2^i$ depends also on values of $M_1^i$, $M_1^k$ and $\eta$. These parameters' effects are:

$$\frac{\partial S_2^i}{\partial M_1^i} < 0,\quad \frac{\partial S_2^i}{\partial M_1^k} > 0,\ \text{and}\ \frac{\partial S_2^i}{\partial \eta}\begin{cases} < 0 & \text{if} \quad \sigma_1^i > \frac{e\left(2b^2-e^2\right)}{(e+b)\left(4b^2-e^2-2be\right)} \\ = 0 & \text{if} \quad \sigma_1^i = \frac{e\left(2b^2-e^2\right)}{(e+b)\left(4b^2-e^2-2be\right)} \\ > 0 & \text{if} \quad \sigma_1^i < \frac{e\left(2b^2-e^2\right)}{(e+b)\left(4b^2-e^2-2be\right)} \end{cases},$$

where $\sigma_1^i$ is exporting country $i$'s first-period market share in the importing country.

Analogously, by using equations (4.13) and (4.19) we can examine when the second period prices are higher compared to the second-period prices of a model without intervention. This relationship is again ambiguous and depends on the values of parameters in the same fashion as did the sign of $S_2^i$. As an example, with larger first period exports it is more likely that an exporting firm charges a higher price and that an export tax is the optimal intervention policy for the government.

We can also compare a market with switching costs to a market without switching costs. In a symmetric equilibrium (which exists, as we see later), such that $M_1^{\,i} = M_1^{\,k} = \frac{1}{2}M_1$, equations (4.18)-(4.21) can be written as:

$$(4.18') \qquad S_2^i = S_2^k = c - \frac{e^2}{b\left(4b^2 - e^2 - 2be\right)}\left[a - (b-e)\bar{\tau} + \tfrac{1}{2}(b-e)\eta M_1\right],$$

$$(4.19') \qquad P_2^i = P_2^k = \frac{2b}{\left(4b^2 - e^2 - 2be\right)}\left[a - (b-e)\bar{\tau} + \tfrac{1}{2}(b-e)\eta M_1\right]$$

$$(4.20') \qquad M_2^i = M_2^k = \frac{\left(2b^2 - e^2\right)}{\left(4b^2 - e^2 - 2be\right)}\left[a - (b-e)\bar{\tau} + \tfrac{1}{2}(b-e)\eta M_1\right]$$

$$(4.21') \qquad \pi_2^i = \pi_2^k = \frac{\left(2b^2 - e^2\right)^2}{b\left(4b^2 - e^2 - 2be\right)^2}\left[a - (b-e)\bar{\tau} + \tfrac{1}{2}(b-e)\eta M_1\right]^2$$

In a market without switching costs (that is $\eta = 0$), in equilibrium

$$(4.22) \qquad S_2^i = S_2^k = c - \frac{e^2}{b\left(4b^2 - e^2 - 2be\right)}\left[a - (b-e)\bar{\tau}\right],$$

$$(4.23) \qquad P_2^i = P_2^k = \frac{2b}{\left(4b^2 - e^2 - 2be\right)}\left[a - (b-e)\bar{\tau}\right],$$

$$(4.24) \qquad M_2^i = M_2^k = \frac{\left(2b^2 - e^2\right)}{\left(4b^2 - e^2 - 2be\right)}\left[a - (b-e)\bar{\tau}\right],$$

$$(4.25) \qquad \pi_2^i = \pi_2^k = \frac{\left(2b^2 - e^2\right)^2}{b\left(4b^2 - e^2 - 2be\right)^2}\left[a - (b-e)\bar{\tau}\right]^2.$$

By comparing equations (4.18')-(4.21') to equations (4.22)-(4.25) it can easily be seen that in the symmetric equilibrium the profits, prices and exports of both firms are higher, and export subsidies (export taxes) are lower (higher), in the second period of a market with switching costs than in a market without switching costs. The reason is that each firm has an opportunity to raise price in the second period to exploit the consumers who initially bought its wheat. Switching costs reduce consumers' flexibility, and thereby reduce firms' elasticities of demand, leading to the less competitive outcomes – higher price with higher profits. Higher prices imply that lower export subsidies are needed in the second period. These results are consistent with the results of To (1994) and Klemperer (1987b)[12].

### 4.1.2. The First Period

#### 4.1.2.1. The Importing Country's Problem

In the first period, the importing country has no ties to any particular exporting country. Each firm (exporting country) sets its price (export subsidy) while taking into account not only the effect on its first-period profitability (welfare), but also the effect on its first-period market share and hence second-period profitability (welfare).

The form of importer expectations determines how market shares depend on first-period prices. For simplicity, we look at the case of "naive expectations", in which the importer does not take the second-period into account when making first-period decisions.

In this case first-period imports are determined as if there were no switching costs[13,14]:

$$M_1^i\left(P_1^i, P_1^k\right) = a - b\left(P_1^i + \overline{\tau}\right) + e\left(P_1^k + \overline{\tau}\right). \tag{4.26}$$

#### 4.1.2.2. The Exporting Firm's Problem

In the first-period each firm aims to maximize its total discounted future profits by choosing first-period prices, given its government's choice of subsidies, and knowing how their first-period choice will affect decisions and profits in the future. Firm $i$'s discounted profits are $\pi^i = \pi_1^i + \delta\pi_2^i$, where $\delta$ is the discount factor of both firms and governments. Using (4.21) and (4.26) it follows that

[12] Klemperer's model is not an international trade model, but the effects on prices and profits of firms are essentially the same as here.

[13] This import demand function was derived at the beginning of the section (see equation (4.5)).

[14] Note that all parameters are positive and $b > e$.

$$\pi^i\left(P_1^i, P_1^k\right) = \left(P_1^i + S_1^i - c\right)\left(a - (b-e)\overline{\tau} - bP_1^i + eP_1^k\right)$$

(4.27)
$$+\frac{\delta\left(2b^2 - e^2\right)^2}{b\left(4b^2 - e^2 - 2be\right)^2}\left[a - (b-e)\overline{\tau} + \frac{b\left(4b^2 - 3e^2\right)\eta}{\left(4b^2 - e^2 + 2be\right)}\right.$$
$$\left.\cdot\left(a - (b-e)\overline{\tau} - bP_1^i + eP_1^k\right) - \frac{e\left(2b^2 - e^2\right)\eta}{\left(4b^2 - e^2 + 2be\right)}\left(a - (b-e)\overline{\tau} - bP_1^k + eP_1^i\right)\right]^2$$

$$\frac{\partial \pi^i}{\partial P_1^i} = a - (b-e)\overline{\tau} - 2bP_1^i + eP_1^k + bc - bS_1^i - \frac{2\delta\left(2b^2 - e^2\right)^2}{b\left(4b^2 - e^2 - 2be\right)^2}\left[a - (b-e)\overline{\tau}\right.$$
$$+\frac{b\left(4b^2 - 3e^2\right)\eta}{\left(4b^2 - e^2 + 2be\right)}\left(a - (b-e)\overline{\tau} - bP_1^i + eP_1^k\right) - \frac{e\left(2b^2 - e^2\right)\eta}{\left(4b^2 - e^2 + 2be\right)}$$
$$\left.\cdot\left(a - (b-e)\overline{\tau} - bP_1^k + eP_1^i\right)\right] \cdot \frac{\eta\left(4b^4 - b^2e^2 - e^4\right)}{\left(4b^2 - e^2 + 2be\right)} = 0.$$

The second-order condition for the firm's first-period problem is

$$\frac{\partial^2 \pi^i}{\left(\partial P_1^i\right)^2} = -2b + \frac{2\delta\eta^2\left(2b^2 - e^2\right)^2\left(4b^4 - b^2e^2 - e^4\right)^2}{b\left(4b^2 - e^2 - 2be\right)^2\left(4b^2 - e^2 + 2be\right)^2} < 0.$$

This second-order condition does not hold for all parameter values. The remainder of the chapter assumes that the second-order condition is satisfied, i.e.,

$$b^2\left[\left(4b^2 - e^2\right)^2 - (2be)^2\right]^2 > \delta\eta^2\left(2b^2 - e^2\right)^2\left(4b^4 - b^2e^2 - e^4\right)^2.$$

Using the first-order condition we can solve for the firm's best-response function:

(4.28)
$$P_1^i\left(P_1^k\right) = \mathrm{A}\left(a - (b-e)\overline{\tau}\right) + \mathrm{B}P_1^k + \mathrm{E}\left(c - S_1^i\right),$$

$$\text{where}\quad A=\frac{\left[1-\dfrac{2\delta\eta\left(2b^2-e^2\right)^2\left(4b^2-e^2+2be\right)\left(4b^4-b^2e^2-e^4\right)\left(1+(b-e)\eta\right)}{b\left[\left(4b^2-e^2\right)^2-(2be)^2\right]^2}\right]}{\left[2b-\dfrac{2\delta\eta^2\left(2b^2-e^2\right)^2\left(4b^4-b^2e^2-e^4\right)^2}{b\left[\left(4b^2-e^2\right)^2-(2be)^2\right]^2}\right]},$$

$$B=\frac{\left[e-\dfrac{4\delta\eta^2be\left(2b^2-e^2\right)^2\left(4b^4-b^2e^2-e^4\right)\left(3b^2-2e^2\right)}{b\left[\left(4b^2-e^2\right)^2-(2be)^2\right]^2}\right]}{\left[2b-\dfrac{2\delta\eta^2\left(2b^2-e^2\right)^2\left(4b^4-b^2e^2-e^4\right)^2}{b\left[\left(4b^2-e^2\right)^2-(2be)^2\right]^2}\right]},\ \text{and}$$

$$E=\frac{b}{\left[2b-\dfrac{2\delta\eta^2\left(2b^2-e^2\right)^2\left(4b^4-b^2e^2-e^4\right)^2}{b\left[\left(4b^2-e^2\right)^2-(2be)^2\right]^2}\right]}.$$

Note that the sign of B determines when the best-response functions are upward or downward sloping as functions of the other firm's price. Following Bulow et al. (1985), competitors regard their actions as strategic complements when $B>0$ and strategic substitutes when $B<0$. With strategic complements firm *i* responds to aggressive play with more aggressive play. In price competition, this means that the firm *i* responds to firm *k*'s lower price by lowering its price. With strategic substitutes firm *i*'s optimal response to more aggressive play by firm *k* is to be less aggressive (*i* increases its price).

A common presumption is that with price competition the goods (wheats) are strategic complements ($B>0$), but it can be seen from above that determination of whether goods are strategic substitutes or strategic complements cannot be made without empirically analyzing the market. The shape of the demand function is critical.

Using the best-response functions, first-period prices can be solved as a function of export subsidies:

(4.29) $$P_1^i = \frac{1}{(1-\mathrm{B})}\left[\mathrm{A}\left(a-(b-e)\bar{\tau}\right)+\mathrm{E}c-\frac{\mathrm{E}}{(1+\mathrm{B})}\left(S_1^i+\mathrm{B}S_1^k\right)\right].$$

Closer examination of A and B shows that B < ½, and that A can be positive or negative. If A is negative then the exporting firm dumps its wheat in the first period in order to capture a larger market share. Therefore, dumping can be seen as a rational behavior of the exporting firm when there are switching costs in the market.

Substituting (4.29) into the import demand function (equation (4.26)) we find the first-period equilibrium exports of country $i$:

(4.30) $$\begin{aligned} M_1^i = \frac{1}{1-\mathrm{B}}\Big[&\left(1-\mathrm{B}-(b-e)\mathrm{A}\right)\left(a-(b-e)\bar{\tau}\right)-(b-e)\mathrm{E}c \\ &+\frac{\mathrm{E}}{1+\mathrm{B}}\left((b-e\mathrm{B})S_1^i-(e-b\mathrm{B})S_1^k\right)\Big], \end{aligned}$$

Substituting (4.30) into (4.19) and (4.20) we get second-period prices and exports as a function of first-period export subsidies:

(4.31) $$\begin{aligned} P_2^i = \frac{2b}{\left(4b^2-e^2-2be\right)}\Bigg\{&\left(1+(b-e)\eta\left(1-\frac{(b-e)A}{1-B}\right)\right)\left(a-(b-e)\bar{\tau}\right)-\frac{(b-e)^2E\eta}{1-B}c \\ &+\frac{E\eta}{\left(1-B^2\right)\left(4b^2-e^2+2be\right)}\cdot\Big[\left(b\left(4b^2-3e^2\right)(bB-e)-e\left(2b^2-e^2\right)(b-eB)\right)S_1^i \\ &+\left(b\left(4b^2-3e^2\right)(b-eB)+e\left(2b^2-e^2\right)(e-bB)\right)S_1^k\Big]\Bigg\}, \end{aligned}$$

(4.32) $$\begin{aligned} M_2^i = \frac{\left(2b^2-e^2\right)}{\left(4b^2-e^2-2be\right)}\Bigg\{&\left(1+(b-e)\eta\left(1-\frac{(b-e)A}{1-B}\right)\right)\left(a-(b-e)\bar{\tau}\right)-\frac{(b-e)^2E\eta}{1-B}c \\ &+\frac{E\eta}{\left(1-B^2\right)\left(4b^2-e^2+2be\right)}\cdot\Big[\left(b\left(4b^2-3e^2\right)(bB-e)-e\left(2b^2-e^2\right)(b-eB)\right)S_1^i \\ &+\left(b\left(4b^2-3e^2\right)(b-eB)+e\left(2b^2-e^2\right)(e-bB)\right)S_1^k\Big]\Bigg\}. \end{aligned}$$

#### 4.1.2.3. The Exporting Government's Problem

Governments maximize their countries' discounted welfare, given that they know how firms and the importing country will behave in the future. Country $i$'s discounted welfare is

$$(4.33)\quad W^i = \left(P_1^i + S_1^i\right)M_1^i - S_1^i M_1^i + \delta\left[\left(P_2^i - S_2^i\right)M_2^i - S_2^i M_2^i\right] = P_1^i M_1^i + \delta P_2^i M_2^i,$$

where the first term is the firm's first period net revenue and the second term equals discounted second period net revenue. The first- and second-order conditions for country $i$'s problem are

$$\frac{\partial W^i}{\partial S_1^i} = \frac{\mathrm{E}}{\left(1-\mathrm{B}^2\right)}\Bigg[(b-e\mathrm{B})P_1^i - M_1^i + \frac{4\delta b\eta\left(b\left(4b^2-3e^2\right)(b-e\mathrm{B}) + e\left(2b^2-e^2\right)(e-b\mathrm{B})\right)}{\left(4b^2-e^2\right)^2-(2be)^2}M_2^i\Bigg] = 0$$

and

$$\frac{\partial^2 W^i}{\left(\partial S_1^i\right)^2} = \frac{2\mathrm{E}^2}{\left(1-\mathrm{B}^2\right)^2}\Bigg[-(b-e\mathrm{B}) + \frac{2\delta b\eta^2\left(2b^2-e^2\right)\left(b\left(4b^2-3e^2\right)(b-e\mathrm{B}) + e\left(2b^2-e^2\right)(e-b\mathrm{B})\right)^2}{\left[\left(4b^2-e^2\right)^2-(2be)^2\right]^2}\Bigg] < 0.$$

Note that the country's second-order condition does not always hold, and it is more restrictive than the firm's second-order condition. It is assumed here that the second-order condition is satisfied, i.e.,

$$(b-e\mathrm{B})\left[\left(4b^2-e^2\right)^2-(2be)^2\right]^2 > 2\delta b\eta^2\left(2b^2-e^2\right)\cdot\left(b\left(4b^2-3e^2\right)(b-e\mathrm{B}) + e\left(2b^2-e^2\right)(e-b\mathrm{B})\right)^2.$$

Using the first-order conditions we can solve for first-period equilibrium export subsidies. Since each government's best-response function is linear in the other government's export subsidy it follows that the equilibrium is unique. Substituting the equilibrium subsidy levels into (4.29) and (4.30) yields first-period prices and export volumes as functions of $\delta, c, \eta, \bar{\tau}, a, b,$ and $e$. Also, first-period profits can be computed:

$$(4.34)\quad S_1^i = S_1^k = c + \frac{1}{E}\left[ A - \frac{(1-B)\left[(4b^2 - e^2 + 2be)(4b^2 - e^2 - 2be)^2 - 4\delta b\eta(2b^2 - e^2) \cdot (1 + \eta(b-e))\left(4b^4 - b^2e^2 - e^4 - 2beB(3b^2 - 2e^2)\right)\right]}{\left[(2b - e(1+B))(4b^2 - e^2 + 2be)(4b^2 - e^2 - 2be)^2 - 4\delta b\eta^2 (2b^2 - e^2)(b-e)^2\left(4b^4 - b^2e^2 - e^4 - 2beB(3b^2 - 2e^2)\right)\right]} \right](a - (b-e)\bar{\tau}),$$

$$(4.35)\quad P_1^i = P_1^k = \left[ \frac{\left[(4b^2 - e^2 + 2be)(4b^2 - e^2 - 2be)^2 - 4\delta b\eta(2b^2 - e^2) \cdot (1 + \eta(b-e))\left(4b^4 - b^2e^2 - e^4 - 2beB(3b^2 - 2e^2)\right)\right]}{\left[(2b - e(1+B))(4b^2 - e^2 + 2be)(4b^2 - e^2 - 2be)^2 - 4\delta b\eta^2 (2b^2 - e^2)(b-e)^2\left(4b^4 - b^2e^2 - e^4 - 2beB(3b^2 - 2e^2)\right)\right]} \right](a - (b-e)\bar{\tau}),$$

$$(4.36)\quad M_1^i = M_1^k = \left[ \frac{\left[(b - eB)(4b^2 - e^2 + 2be)(4b^2 - e^2 - 2be)^2 + 4\delta b\eta(2b^2 - e^2) \cdot (b-e)\left(4b^4 - b^2e^2 - e^4 - 2beB(3b^2 - 2e^2)\right)\right]}{\left[(2b - e(1+B))(4b^2 - e^2 + 2be)(4b^2 - e^2 - 2be)^2 - 4\delta b\eta^2 (2b^2 - e^2)(b-e)^2\left(4b^4 - b^2e^2 - e^4 - 2beB(3b^2 - 2e^2)\right)\right]} \right](a - (b-e)\bar{\tau}),$$

$$(4.37)\quad \pi_1^i = \pi_1^k = \frac{1}{(1-\mathrm{B})}\left[\mathrm{A}(a - (b-e)\bar{\tau}) - (1 - (\mathrm{B}+\mathrm{E}))(c - S_1^*)\right]\left[a - (b-e)\bar{\tau} - \frac{(b-e)}{(1-\mathrm{B})}\left[\mathrm{A}(a - (b-e)\bar{\tau}) + \mathrm{E}(c - S_1^*)\right]\right],$$

where $S_1^*$ is defined by equation (4.34).

Using these equations, several interesting observations can be made. From equation (4.34) it can be seen that the sign of $(S_1^i)$ is ambiguous and cannot be determined without empirically analyzing the market. However, it is intuitive that with larger values of switching costs (and with a larger discount factor) an export subsidy is more likely (i.e., $\partial S_1^i / \partial\eta > 0$, $\partial S_1^i / \partial\delta > 0$). That is, export subsidies are more likely to appear under parameter values which cause the customer base to be more locked-in during the second period.

Unfortunately, the analytical proof of this result is beyond our ability, and we were therefore forced to numerically approximate these comparative statics results.[15] Appendix A illustrates this numerical analysis.

Since the importing country develops switching costs after making its initial purchases, the second-period prices and profits (and exporting countries' welfares) are higher and export subsidies are lower compared with prices, profits and subsidies in the first period. In the first period, firms compete for market share which is valuable later, and firms raise their prices in the second period to take advantage of the fact that their first-period customer has become partly locked in to them as suppliers.

Finally, first-period prices and profits (and exporting countries' welfares) are lower and export subsidies are higher than in a market without switching costs. Since market share is more valuable to firms the higher are switching costs (i.e., $\partial\left(\partial \pi_2^i / \partial \sigma^i\right) / \partial \eta > 0$), switching costs make firms compete more aggressively for market share in the first period than they would if they were simply maximizing first-period profits: $\partial P_1^i / \partial \eta < 0$, $\partial \pi_1^i / \partial \eta < 0$, and $\partial S_1^i / \partial \eta > 0$.

The next step in this dissertation is to extend this two-period model to a multiperiod framework in which firms can alter prices and governments can alter export subsidies freely in any period. This multiperiod model is then used in the empirical analysis of the international wheat trade.

## 4.2. Finite Period Dynamic International Wheat Trade Model with Switching Costs

In the previous section a two-period international trade model with switching costs was described and analyzed in detail. In the second period of that model, the exporting countries' ability to lock-in the importing country to some degree led to higher prices being charged by exporting firms' and to lower export subsidies set by exporting countries' governments than if there were no switching costs. In the first period, therefore, firms set lower prices and governments' announce larger subsidies than if there were no switching costs, in order to capture market share that will be valuable in the second period.

[15] We can derive the partial derivatives, $\partial S_1^i / \partial \eta > 0$, $\partial S_1^i / \partial \delta > 0$, but signing them analytically has proven to be a very difficult task. Naturally, the use of numerical analysis is not a proof. However, the supportive conclusion of the numerical analysis is that for all the parameter values tried the sign of partial derivatives are as expected. That is, we could not find a counterexample. The next paragraph states a few more interesting observations. Unfortunately, the same problem of proof applies to them as well, but similar supportive outcomes from the numerical analysis are achieved.

Such a model does not tell us what to expect from competition over many periods. Will exporting countries' temptation to exploit their current market share lead to higher prices and lower subsidies than in the absence of switching costs, or will exporting countries' desire to achieve larger market share lead to lower price and higher export subsidies? Furthermore, the purpose of the two period assumption is to extract theoretical results. Thus, two-period models may not be the most satisfactory for analyzing the effects of policy shocks (e.g., restrictions on export subsidies by GATT) or other shocks since in the real world we have more than two periods and since the "first period" is not usually without historical market shares and switching costs. This section, therefore, extends the two-period model of the previous section into a more general finite-horizon multiperiod model of competition in a market with switching costs.

Other generalizations employed in this section include more general (though linear) import demand functions. In addition, we relax the assumption made by many previous studies that the social cost of public funds is unity: an extra dollar earned in export revenues (or profits, depending on the objective function) by the home firm has the same social valuation as an extra dollar in subsidy payments forgone by the home government. This view implicitly assumes that export subsidies have no distortionary effects on other sectors and that the opportunity cost of public funds is the amount spent. Such an approach does not take into account the welfare costs of distortions caused by collection of taxes elsewhere in the economy to finance government spending on export subsidies. Although the public finance literature does not fully agree on the size of this marginal deadweight cost of taxation, it is generally believed that such costs exist. Estimates for the U.S. economy are between 20 percent and 50 percent (Ballard et al. 1985). Since the cost of public funds becomes a determinant of the design of optimal export policy, we assume that governments maximize the domestic firm's export revenues less the cost of transfers to the firm.[16] Finally, in contrast to the two-period model, asymmetric non-zero marginal costs are allowed.

In our finite-horizon dynamic model of international wheat trade, governments of exporting countries in each period set export subsidies to maximize their discounted future net revenues (home-firm revenues minus costs of the subsidy program), given the history of the game and expected behavior of the firms and the importing country in the future. Then in each period the exporting firms set their prices to maximize discounted future profits, given government subsidies and the history of the game. Because of switching costs, the importing country's behavior depends on history, in particular on previous purchases of

[16] Among others, Gruenspecht (1988), Neary (1991), McNally (1993), and Brainard and Martimort (1996) also investigate the impact of a costly public funds in models of strategic trade policy.

the good from a specific country. Therefore, governments' and firms' decisions in one period also have (predictable) effects into the future.

The decisions of both firms and governments are appropriately analyzed as a difference game. We restrict ourselves to analyzing feedback Markovian strategies (feedback state-space strategies) in which the past influences current decisions only through its effect on a current state vector that summarizes the direct effect of the past on the current environment. We look for a Markov perfect (feedback) equilibrium, i.e. a profile of Markov strategies that yields a Nash equilibrium in every proper subgame.

The other major strategy space, in addition to the feedback strategy space, commonly examined in the literature is the open-loop strategy space. However, open-loop strategies have the undesirable property that the associated equilibria may not be subgame perfect. The reasonableness and usefulness of our feedback restriction is discussed in Fudenberg and Tirole (1991). Basically, this Markov restriction rules out other perfect equilibria in which strategies depend on aspects of history which do not directly influence the players' payoffs.

The remainder of the section describes how the game is solved by backward induction. To begin the backward inductive solution for our finite-horizon dynamic game we start at period *T*, which is the final period of our specified time horizon. (At *T+1* the game has ended.)

### 4.2.1. Final Period (*T*)

#### 4.2.1.1. The Exporting Firm's Problem

The firms in both exporting countries choose their prices to maximize terminal period profits given the terminal period export subsidy levels chosen by governments and given firms' exports from the period *T-1*, i.e. given the current state of the game. Firm *i*'s final period profits are

$$\underset{P_T^i}{Max} \quad \Pi_T^i = \left(P_T^i + S_T^i - C_T^i\right)\left(a^i - b^i\left(P_T^i + \overline{\tau} - \eta^i M_{T-1}^i\right) + e\left(P_T^k + \overline{\tau} - \eta^k M_{T-1}^k\right)\right)$$

As in the two-period model, maximizing the objective function with respect to own price we get the best-response function of firm *i*. The intersection of best-response functions for firm *i* and *k* gives the final period prices, the current decision variables (also called the control vector), as a linear function of the current state:

$$(4.38) \qquad P_T^i = K_T^{i0} + K_T^{i1} S_T^i + K_T^{i2} S_T^k + K_T^{i3} M_{T-1}^i + K_T^{i4} M_{T-1}^k ,$$

where $K_T^{ij}$, *j=0,1,2,3,4,* are functions of import demand function parameters and of marginal costs:

$$K_T^{i0} = \frac{2b^k\left(a^i - \left(b^i - e\right)\overline{\tau}\right) + e\left(a^k - \left(b^k - e\right)\overline{\tau}\right) + 2b^i b^k C_T^i + b^k e C_T^k}{4b^i b^k - e^2},$$

$$K_T^{i1} = \frac{-2b^i b^k}{4b^i b^k - e^2}, K_T^{i2} = \frac{-eb^k}{4b^i b^k - e^2}, \; K_T^{i3} = \frac{\left(2b^i b^k - e^2\right)\eta^i}{4b^i b^k - e^2},$$

$$K_T^{i4} = \eta^k K_T^{i2}.$$

Substituting (4.38) and the same equation for firm $k$ into import demand functions yields

(4.39) $$M_T^i = D_T^{i0} + D_T^{i1} S_T^i + D_T^{i2} S_T^k + D_T^{i3} M_{T-1}^i + D_T^{i4} M_{T-1}^k,$$

where $D_T^{i0} = a^i - \left(b^i - e\right)\overline{\tau} - b^i K_T^{i0} + eK_T^{k0}$, $\quad D_T^{i1} = -b^i K_T^{i1} + eK_T^{k2}$,

$D_T^{i2} = -b^i K_T^{i2} + eK_T^{k1}$, $\quad D_T^{i3} = \eta^i D_T^{i1}$, $\quad D_T^{i4} = \eta^k D_T^{i2}$.

Firm behavior in period T is qualitatively the same as firm behavior in the second period of the two-period model (see the comparative statics results of that section). We are now ready to move to the government's optimization problem in the terminal period.

#### 4.2.1.2. The Exporting Government's Problem

The exporting country's government maximizes the country's final period welfare by setting an export subsidy given period *T-1* exports (the current state in the governments' problem) and the expected behavior of the firm. Recall from the two-period model that domestic welfare is measured by total export revenues less expenditures on export subsidies:

$$\underset{S_T^i}{Max} \quad W_T^i = \left(P_T^i + S_T^i\right) M_T^i - S_T^i M_T^i = P_T^i M_T^i.$$

In this preceding analysis subsidy dollars and firms export revenue dollars have been treated as equivalent. As implied by the above welfare function the government is indifferent about pure transfers from the domestic treasury to the firm (or vice versa). In practice, however, each dollar spent by the government is raised through distortionary taxes (labor, capital, and excise taxes) and costs to society $\$(1+\lambda)$, where $\lambda>0$. In other words, ideal lump-sum taxes (which would imply that $\lambda=0$) are not available. Laffont and Tirole (1993) state an important point that the shadow cost of public funds ($\lambda$) is given by economy wide data and is independent of the regulation of the industry under consideration as long as the latter is small relative to the economy.

The measurement of shadow cost of public funds results from the theory of public finance and from the estimation of the elasticities of demand and supply for consumption, labor, and capital. A reasonable mean estimate for U.S. economy seems to be $\lambda$=0.3 (see Ballard et al. 1985). The shadow cost of public funds is likely to be higher in countries where tax collection is less efficient (Laffont and Tirole 1993).

Taking the above aspect into account, we now write the *i*th government's welfare function as

$$\underset{S_T^i}{Max} \quad W_T^i = \left(P_T^i + S_T^i\right)M_T^i - \mu^i S_T^i M_T^i,$$

where $\mu=1+\lambda$ is the opportunity cost of public funds. However, it is important keep in mind that this welfare function is still quite favorable towards the producer interest group since zero weight is given for consumer surplus.

Substituting (4.38) and (4.39) into the government's objective function and taking the first derivative with respect to $S_T{}^i$ yields a first-order condition for maximum welfare. The first-order condition is then solved for $S_T{}^i$ to get country *i*'s best-response function. Similarly, the best-response function is solved for government *k*. Then computing the intersection of the best-response functions yields period *T* equilibrium export subsidies as a linear functions of the current state:

$$S_T^i = H_T^{i0} + H_T^{i1} M_{T-1}^i + H_T^{i2} M_{T-1}^k, \tag{4.40}$$

where $H_T^{ij}$, $j=0,1,2,$ are functions of import demand function parameters, of opportunity cost of public funds parameters, and of marginal costs.

Substituting (4.40) into (4.38), (4.39) and also into the objective functions of firms and governments allows final period equilibrium prices, exports, profits and welfares to be expressed as functions of the current state:

$$P_T^i = E_T^{i0} + E_T^{i1} M_{T-1}^i + E_T^{i2} M_{T-1}^k, \tag{4.41}$$

$$M_T^i = G_T^{i0} + G_T^{i1} M_{T-1}^i + G_T^{i2} M_{T-1}^k, \tag{4.42}$$

$$\begin{aligned}\Pi_T^i\left(M_{T-1}^i, M_{T-1}^k\right) = B_T^{i0} + B_T^{i1} M_{T-1}^i + B_T^{i2} M_{T-1}^k + B_T^{i3}\left(M_{T-1}^i\right)^2 \\ + B_T^{i4}\left(M_{T-1}^k\right)^2 + B_T^{i5} M_{T-1}^i M_{T-1}^k \quad ,\end{aligned} \tag{4.43}$$

and

(4.44)
$$W_T^i\left(M_{T-1}^i, M_{T-1}^k\right) = A_T^{i0} + A_T^{i1} M_{T-1}^i + A_T^{i2} M_{T-1}^k + A_T^{i3}\left(M_{T-1}^i\right)^2 + A_T^{i4}\left(M_{T-1}^k\right)^2 + A_T^{i5} M_{T-1}^i M_{T-1}^k \quad ,$$

where $E_T^{ij}, G_T^{ij}, j=0,1,2,$ and $A_T^{il}, B_T^{il}, l=0,1,2,3,4,5$ are also functions of import demand function parameters, of opportunity cost of public funds parameters and of marginal costs.

### 4.2.2. Period t

After solving for the equilibrium of the terminal period subgame we can move backward to solve for the equilibrium of the subgame consisting of the last two periods, *T-1* and *T*. This procedure is same for any remaining subgame of our dynamic game, so we can show it for a general, *t*th, period, where $t \in [1,T-1]$. Note that when $t=1$ the subgame is the whole dynamic game itself.

#### 4.2.2.1. The Exporting Firm's Problem

In the general *t*th period, each firm aims to maximize its total discounted future profits starting from period *t* by choosing period *t* prices given the current state and knowing how its choice in period *t* will affect decisions and profits in the future. Firm *i*'s total future discounted profits are:

(4.45)
$$\Pi_t^i = \pi_t^i + \delta \Pi_{t+1}^i\left(M_t^i, M_t^k\right),$$

in which its value function from period $t+1$, $\Pi_{t+1}^i$, will depend on period *t* exports. Substitution of (4.43) into (4.45) gives us a following objective function for firm *i*:

$$\underset{P_t^i}{Max} \quad \Pi_t^i = \Big[\left(P_t^i + S_t^i - C_t^i\right)\left(a^i - b^i\left(P_t^i + \overline{\tau} - \eta^i M_{t-1}^i\right) + e\left(P_t^k + \overline{\tau} - \eta^k M_{t-1}^k\right)\right)$$
$$+ \delta\Big(B_{t+1}^{i0} + B_{t+1}^{i1}\left(a^i - b^i\left(P_t^i + \overline{\tau} - \eta^i M_{t-1}^i\right) + e\left(P_t^k + \overline{\tau} - \eta^k M_{t-1}^k\right)\right)$$
$$+ B_{t+1}^{i2}\left(a^k - b^k\left(P_t^k + \overline{\tau} - \eta^k M_{t-1}^k\right) + e\left(P_t^i + \overline{\tau} - \eta^i M_{t-1}^i\right)\right)$$
$$+ B_{t+1}^{i3}\left(a^i - b^i\left(P_t^i + \overline{\tau} - \eta^i M_{t-1}^i\right) + e\left(P_t^k + \overline{\tau} - \eta^k M_{t-1}^k\right)\right)^2$$
$$+ B_{t+1}^{i4}\left(a^k - b^k\left(P_t^k + \overline{\tau} - \eta^k M_{t-1}^k\right) + e\left(P_t^i + \overline{\tau} - \eta^i M_{t-1}^i\right)\right)^2$$
$$+ B_{t+1}^{i5}\left(a^i - b^i\left(P_t^i + \overline{\tau} - \eta^i M_{t-1}^i\right) + e\left(P_t^k + \overline{\tau} - \eta^k M_{t-1}^k\right)\right)$$
$$\cdot\left(a^k - b^k\left(P_t^k + \overline{\tau} - \eta^k M_{t-1}^k\right) + e\left(P_t^i + \overline{\tau} - \eta^i M_{t-1}^i\right)\right)\Big)\Big]$$

Firm $i$'s first-order condition is now[17]

(4.46)
$$\frac{\partial \pi_t^i}{\partial P_t^i} + \delta\left[\frac{\partial \Pi_{t+1}^i}{\partial M_t^i}\frac{\partial M_t^i}{\partial P_t^i} + \frac{\partial \Pi_{t+1}^i}{\partial M_t^k}\frac{\partial M_t^k}{\partial P_t^i}\right] = 0.$$

Digressing for a moment from the solving procedure, we analyze the first-order condition more closely. We obtain here a result consistent with Klemperer (1995). Provided that a lower current price raises the firm's current exports, $\partial M_t^i / \partial P_t^i < 0$, decreases rival firm's current exports, $\partial M_t^k / \partial P_t^i > 0$, and that the firm's future total discounted profits are increasing in its current exports, $\partial \Pi_{t+1}^i / \partial M_t^i > 0$, and decreasing in rival firm's current exports, $\partial \Pi_{t+1}^i / \partial M_t^k < 0$, then we have $\partial \pi_t^i / \partial P_t^i > 0$. That is, the firm prices are lower than they would be if it ignored the fact that its current exports will be valuable in the future. However, as Klemperer (1995) points out, it is important to notice that this does not tell us whether the prices charged by the firms are higher or lower than in the absence of switching costs, because current demand is made more inelastic due to switching costs. In fact the firms are facing a trade-off between setting a high price to exploit their current market share or charging a low current price to build up the current market share and therefore increase future profits. Klemperer goes on to explain that we should expect prices to be generally higher than in the absence of switching costs. This interesting issue,

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[17] Note that to satisfy the second-order condition of firm $i$'s maximization problem the following condition must hold: $-b^i + \delta\left[B_{t+1}^{i3}\left(b^i\right)^2 + B_{t+1}^{i4}(e)^2 - b^i e B_{t+1}^{i5}\right] < 0$.

among other hypotheses, will be tested using our empirical simulation model in Chapter VI.

Rearranging the first-order condition, we get the firm $i$'s best-response function. Similarly, from exporting firm $k$'s optimization problem we get firm $k$'s best-response function. The intersection point of the two firms' best-response functions gives equilibrium prices as a linear function of the current state (the same period export subsidies and previous period export volumes)

$$(4.47) \qquad P_t^i = K_t^{i0} + K_t^{i1} S_t^i + K_t^{i2} S_t^k + K_t^{i3} M_{t-1}^i + K_t^{i4} M_{t-1}^k$$

where $K_T^{ij}$, $j$=0,1,2,3,4, are functions of import demand function parameters, of opportunity cost of public funds parameters, of marginal costs, and of a discount factor.

By substituting (4.47) and the same equation for firm $k$ into the import demand function we achieve period $t$ equilibrium exports of country $i$:

$$(4.48) \qquad M_t^i = D_t^{i0} + D_t^{i1} S_t^i + D_t^{i2} S_t^k + D_t^{i3} M_{t-1}^i + D_t^{i4} M_{t-1}^k,$$

where $D_t^{i0} = a^i - (b^i - e)\overline{\tau} - b^i K_t^{i0} + eK_t^{i0}$, $\quad D_t^{i1} = -b^i K_t^{i1} + eK_t^{k2}$,

$D_t^{i2} = -b^i K_t^{i2} + eK_t^{k1}$, $\quad D_t^{i3} = -b^i K_t^{i3} + eK_t^{k4} + \eta^i b^i$,

$D_t^{i4} = -b^i K_t^{i4} + eK_t^{k3} - \eta^k e$.

We have now completed the second stage of the period $t$ solution process. So far, firms' price rules have been solved treating the export subsidies of both governments and previous period export volumes as exogenous to firms' profit maximization problem. To solve for governments' export subsidy rules we need to look at the government's optimization problem.

#### 4.2.2.2. The Exporting Government's Problem

Governments maximize their countries' discounted welfare starting from period $t$ given previous period exports and given that they know how firms and the importing country will behave in the future. Country $i$'s discounted welfare is

$$(4.49) \quad W_t^i = w_t^i + \delta W_{t+1}^i\left(M_t^i, M_t^k\right) = \left(P_t^i - \left(\mu^i - 1\right)S_t^i\right)M_t^i + \delta W_{t+1}^i\left(M_t^i, M_t^k\right),$$

or more explicitly for our demand structure,

$$\underset{S_t^i}{Max} \quad W_t^i = \left(K_t^{i0} + K_t^{i1}S_t^i + K_t^{i2}S_t^k + K_t^{i3}M_{t-1}^i + K_t^{i4}M_{t-1}^k - \left(\mu^i - 1\right)S_t^i\right)$$
$$\cdot\left(D_t^{i0} + D_t^{i1}S_t^i + D_t^{i2}S_t^k + D_t^{i3}M_{t-1}^i + D_t^{i4}M_{t-1}^k\right)$$
$$+\delta\Big[A_{t+1}^{i0} + A_{t+1}^{i1}\left(D_t^{i0} + D_t^{i1}S_t^i + D_t^{i2}S_t^k + D_t^{i3}M_{t-1}^i + D_t^{i4}M_{t-1}^k\right)$$
$$+ A_{t+1}^{i2}\left(D_t^{k0} + D_t^{k1}S_t^k + D_t^{k2}S_t^i + D_t^{k3}M_{t-1}^k + D_t^{k4}M_{t-1}^i\right)$$
$$+ A_{t+1}^{i3}\left(D_t^{i0} + D_t^{i1}S_t^i + D_t^{i2}S_t^k + D_t^{i3}M_{t-1}^i + D_t^{i4}M_{t-1}^k\right)^2$$
$$+ A_{t+1}^{i4}\left(D_t^{k0} + D_t^{k1}S_t^k + D_t^{k2}S_t^i + D_t^{k3}M_{t-1}^k + D_t^{k4}M_{t-1}^i\right)^2$$
$$+ A_{t+1}^{i5}\left(D_t^{i0} + D_t^{i1}S_t^i + D_t^{i2}S_t^k + D_t^{i3}M_{t-1}^i + D_t^{i4}M_{t-1}^k\right)$$
$$\cdot\left(D_t^{k0} + D_t^{k1}S_t^k + D_t^{k2}S_t^i + D_t^{k3}M_{t-1}^k + D_t^{k4}M_{t-1}^i\right)\Big].$$

Maximizing with respect to its period-*t* export subsidy (tax if negative), government *i*'s first-order condition is now[18]

$$\text{(4.50)} \qquad \frac{\partial w_t^i}{\partial S_t^i} + \delta\left[\frac{\partial W_{t+1}^i}{\partial M_t^i}\frac{\partial M_t^i}{\partial S_t^i} + \frac{\partial W_{t+1}^i}{\partial M_t^k}\frac{\partial M_t^k}{\partial S_t^i}\right] = 0.$$

Digressing again for a moment from the solving procedure, we analyze this first-order condition more closely. Provided that a higher current export subsidy raises the exporting country's current exports, $\partial M_t^i / \partial S_t^i > 0$, decreases rival country's current exports, $\partial M_t^k / \partial S_t^i < 0$, and that the country's future total discounted welfare is increasing in its current exports, $\partial W_{t+1}^i / \partial M_t^i > 0$, and decreasing in rival country's current exports, $\partial W_{t+1}^i / \partial M_t^k < 0$, then we have $\partial w_t^i / \partial S_t^i < 0$. That is, the exporting country's government sets export subsidies higher than it would if it ignored the fact that its current exports will be valuable in the future. However, Klemperer's point applies here as well. That is, this does not tell us whether the export subsidies set by the governments are higher or lower than in the absence of switching costs, because current demand is made more inelastic by the switching costs. If prices are expected to be

[18] Note that to satisfy the second-order condition of government *i*'s maximization problem the following condition must hold: $\left(1 - \mu^i + K_t^{i1}\right)D_t^{i1} + \delta\left[A_{t+1}^{i3}\left(D_t^{i1}\right)^2 + A_{t+1}^{i4}\left(D_t^{k2}\right)^2 + A_{t+1}^{i5}D_t^{i1}D_t^{k2}\right] < 0$.

generally higher than in the absence switching costs, then we would expect export subsidies to be generally lower than in the absence of switching costs. This hypothesis will also be tested in Chapter VI.

Using first-order conditions for government $i$ and government $k$ and computing the intersection yields period $t$ export subsidies (taxes if negative) as a linear function of the current state:

$$S_t^i = H_t^{i0} + H_t^{i1} M_{t-1}^i + H_t^{i2} M_{t-1}^k, \tag{4.51}$$

where $H_T^{ij}$, $j=0,1,2$, are functions of import demand function parameters, of opportunity cost of public funds parameters, of marginal costs, and of the discount factor.

Substituting (4.51) into (4.47) and (4.48) yields general, $t$th, period prices and export volumes as linear functions of previous period export volumes:

$$P_t^i = E_t^{i0} + E_t^{i1} M_{t-1}^i + E_t^{i2} M_{t-1}^k, \tag{4.52}$$

where $E_t^{i0} = K_t^{i0} + K_t^{i1} H_t^{i0} + K_t^{i2} H_t^{k0}$, $\quad E_t^{i1} = K_t^{i1} H_t^{i1} + K_t^{i2} H_t^{k2} + K_t^{i3}$,

$E_t^{i2} = K_t^{i1} H_t^{i2} + K_t^{i2} H_t^{k1} + K_t^{i4}$,

and

$$M_t^i = G_t^{i0} + G_t^{i1} M_{t-1}^i + G_t^{i2} M_{t-1}^k, \tag{4.53}$$

where $G_t^{i0} = D_t^{i0} + D_t^{i1} H_t^{i0} + D_t^{i2} H_t^{k0}$, $\quad G_t^{i1} = D_t^{i1} H_t^{i1} + D_t^{i2} H_t^{k2} + D_t^{i3}$,

$G_t^{i2} = D_t^{i1} H_t^{i2} + D_t^{i2} H_t^{k1} + D_t^{i4}$.

where $E_T^{ij}, G_T^{ij}$, $j=0,1,2$, are functions of import demand function parameters, of opportunity cost of public funds parameters, of marginal costs, and of the discount factor.

Finally, by substituting (4.52) and (4.53) into government $i$'s objective function and firm $i$'s objective function yields

$$\begin{aligned} W_t^i\left(M_{t-1}^i, M_{t-1}^k\right) = {} & A_t^{i0} + A_t^{i1} M_{t-1}^i + A_t^{i2} M_{t-1}^k + A_t^{i3}\left(M_{t-1}^i\right)^2 + A_t^{i4}\left(M_{t-1}^k\right)^2 \\ & + A_t^{i5} M_{t-1}^i M_{t-1}^k \quad , \end{aligned} \tag{4.54}$$

$$\Pi_t^i\left(M_{t-1}^i, M_{t-1}^k\right) = B_t^{i0} + B_t^{i1} M_{t-1}^i + B_t^{i2} M_{t-1}^k + B_t^{i3}\left(M_{t-1}^i\right)^2 + B_t^{i4}\left(M_{t-1}^k\right)^2 + B_t^{i5} M_{t-1}^i M_{t-1}^k \quad , \tag{4.55}$$

where $A_T^{ij}$ and $B_T^{ij}$, $j=0,1,2,3,4,5,$ are functions of import demand function parameters, of opportunity cost of public funds parameters, of marginal costs, and of the discount factor.

This completes our solution procedure for a general, *t*th, period. By backward induction we have solved the price rules for firm *i* and *k* as well as export subsidy rules for governments *i* and *k*. To get the solution for the whole dynamic game we need to repeat this procedure for the entire time horizon starting at period *T* and moving backwards to period *1*. After all of the rules are found for each time period, the system is solved forward one period at a time given initial export volumes ($M_0^i$ and $M_0^k$) to find equilibrium paths of prices, subsidies, export volumes and other variables. from the rules found through backward induction.

## 4.3. Conclusions

This chapter developed a theoretical framework for international commodity trade in which switching costs are present and export subsidies (or taxes) are used as policy instruments by exporting countries.

In the two-period model since an importing country develops switching costs after making its initial purchases, the second-period prices and profits (and exporting countries' welfares) are higher and export subsidies are lower when compared with prices, profits and subsidies in the first period. In the first period, firms compete for market share which is valuable later, and firms raise their prices in the second period to take advantage of the fact that their first-period customer has become partly locked in to them as suppliers. Furthermore, first-period prices and profits (and exporting countries' welfares) are lower and export subsidies are higher than in a market without switching costs. Since market share is more valuable to firms the higher are switching costs, switching costs make firms compete more aggressively for market share in the first period than they would if they were simply maximizing first-period profits.

In the second section of this chapter the two-period model was extended to a multiperiod model in which firms can alter prices and governments can alter export subsidies freely in any period. This difference game should provide us a plausible model for evaluating the effects of export promotions. It is used in the subsequent empirical analysis of international wheat trade in Chapter VI.

# CHAPTER V

## DATA AND EMPIRICAL ESTIMATES OF BEHAVIORAL EQUATIONS

In the empirical case study of this dissertation we use the conceptual framework in Chapter IV to analyze competition between EU and U.S. wheat in Morocco. One way to proceed from the conceptual framework to subsequent empirical models would be to use trade elasticities from previous studies to derive needed parameter values for the importing country's import demand functions by exporter (source) (as done by McNally). However, the use of elasticities from earlier studies has been criticized by many (e.g. Sheldon 1992) because in many cases assumptions in previous research do not fit well the conceptual framework employed[1]. As Dixit (1988) points out, it would be a great improvement to have the demand parameters estimated by systematic econometrics, instead of calibrating them. Thus, to ensure consistency between the theoretical model and subsequent empirical models, this study re-estimates Moroccan import demand functions for EU and U.S. wheat utilizing a structure that corresponds to the theoretical framework presented in chapter IV. Another reason for econometric estimation is to analyze the statistical significance of switching cost parameters in order to validate our new agricultural trade modeling approach.

Data limitations require that one small modification of the theoretical model is needed before it can be applied empirically. Recall that the import demand function for exporting country *i*'s wheat at time *t* is:

$$M_t^i = a^i - b^i\left(P_t^i + \bar{\tau} - \eta^i M_{t-1}^i\right) + e\left(P_t^k + \bar{\tau} - \eta^k M_{t-1}^k\right), \tag{5.1}$$

where $i,k$ = EU, U.S. and $\bar{\tau}$ equals all other costs, excluding the price charged by the exporter, associated with the purchase of the product (i.e., transactions costs, learning costs, etc.). Switching costs are captured by the terms $\eta^i M_{t-1}^i$ and $\eta^k M_{t-1}^k$, where $\eta^i$ and $\eta^k$ are marginal switching cost parameters. The idea of switching costs is that larger values for $\eta^i$ or $M_{t-1}^i$ make costs of purchasing again from exporter *i* smaller, so the importing country is less willing to switch to exporter *k*'s wheat.

[1] For example, McCorriston and Sheldon (1991), in their simulation model of the UK fertilizer industry used an external estimate of the elasticity of demand based on empirical work conducted in the 1960s and an estimate of the elasticity of substitution between domestically produced fertilizers and imports based on an Australian estimate.

The empirical problem with equation (5.1) is that reliable proxies for $\bar{\tau}$ turn out to be extremely difficult to obtain. On the other hand, $\bar{\tau}$ only causes an equal size, additional cost to buy both EU and U.S. wheat, as shown in equation (5.1). Therefore, it can be seen just as an equally sized specific tax on both EU and U.S. wheat that shifts import demand functions either inward or outward. Hence, with no changes in the qualitative results of Chapter IV, we can rewrite import demand functions as:

$$(5.2) \qquad M_t^i = z^i - b^i\left(P_t^i - \eta^i M_{t-1}^i\right) + e\left(P_t^k - \eta^k M_{t-1}^k\right),$$

where $z^i = a^i - \left(b^i - e\right)\bar{\tau}$. Data required to estimate import demand functions of this form are available. Therefore, these modified forms of import demand functions are estimated in this chapter and applied in the empirical simulation models found in the next chapter.

This chapter is organized as follows. The following section offers a description of the data set used in the estimation. The estimation methodology section then presents an overview of the Heckman two-step method which addresses the fact that the continuous dependent variable only takes a limited range of values.[2] Its application to the problem of estimating import demand for wheat is described next. In the final section, estimated Moroccan import demand functions for EU and U.S. wheat are analyzed.

## 5.1. Description of Data

Estimation of the values of the coefficients of both import demand functions requires data on variables in the model. Our study differs from most earlier studies that estimate behavioral equations in international wheat trade in that we use monthly data instead of annual data. Monthly data are preferred because strategic interaction between players in the market happens on a transaction by transaction basis. One important goal of this research is to capture that behavior. Use of annual data would conceal much of the strategic interaction occurring in this market.

Data needs for import demand function estimation consist of imported wheat quantities from the EU and U.S. to Morocco and corresponding wheat import prices paid by Morocco. The price data and the quantity data in regularly published sources, such as *World Grain Statistics*, do not match these data needs directly. Therefore, manipulation of the data is required.

[2] In our problem wheat imports by source are always nonnegative.

Data on monthly wheat export volumes for the U.S. can be found in *Foreign Agricultural Trade of the United States* (FATUS), published by the U.S. Department of Agriculture. As far as we know, a similar publication for EU does not exist.

*World Grain Statistics* (formerly World Wheat Statistics) of the International Grain Council (IGC) is probably the best data source on international wheat trade. Trade data are based on monthly reports provided by grain exporting countries, including the U.S. and member states of the EU, among others. With the cooperation by IGC, we were able to access their most recent monthly trade flow data. Time series cover exports of EU and U.S. wheat to Morocco for 47 months from July 1992 to May 1996. This export volume data is shown in Figure 5.1 below as well as in Appendix B.

The wheat prices of interest here are those paid by Morocco at the Moroccan border. Since this data on import prices is not readily available, we derived proxies for import prices as follows. IGC, in *World Grain Statistics*, publishes average monthly export price quotations (fob) for EU wheat and U.S. wheats. For EU wheat only one monthly fob-price is given. This price is net of export refunds, and is that established by open market tenders for export to various specified zones. For the U.S. wheat fob-prices are published for several U.S. ports and wheat varieties. Prices for no. 2 hard winter wheat and no. 2 soft red winter wheat at the Gulf port are used in this research, since mainly winter wheat varieties are exported to Morocco, and since the majority of winter wheats (approximately 80 percent during 1984/85-1993/94) are exported through the U.S. Gulf port (IGC).

A difference between published EU and U.S. prices is that the first one is net of export refunds while the latter is given before subtraction of EEP bonuses. *World Grain Statistics* reports monthly time series on EEP bonuses for common

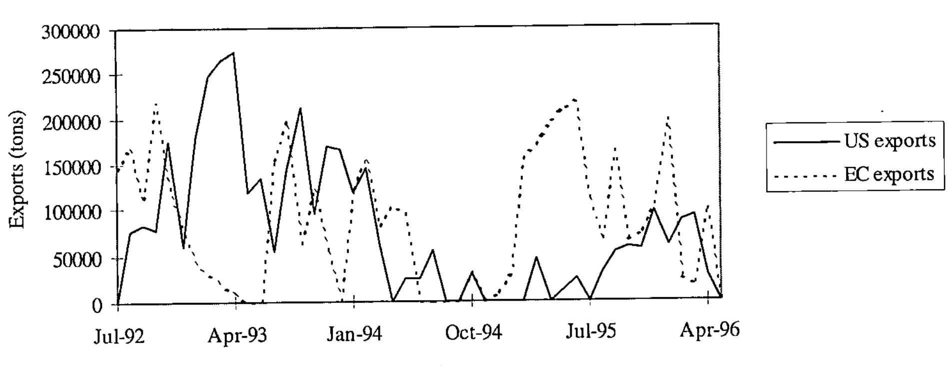


*Figure 5.1. Monthly Wheat Exports From EU and U.S. to Morocco.*

wheat, but they only show the lowest and the highest EEP-bonus for each month to all destinations (combined). USDA's Foreign Agricultural Service (FAS) press releases are a better source on EEP-bonuses, since they provide data on awarded bonuses by destination and wheat type (USDA). This information was used to calculate fob-prices for the U.S. wheat (exported to Morocco) net of EEP bonuses.

Since wheat prices needed for the estimation of import demand functions are the prices paid by Morocco at the Moroccan border, the fob prices net of export subsidies need to be further modified. Transportation charges are added to fob prices to achieve the price data used in the estimation. Mid-month average freight rates for heavy grain[3] on selected routes are also published in *World Grain Statistics*. Freight rates for routes EU to Casablanca and U.S. Gulf to Casablanca are added as transportation costs to obtain imported wheat prices. This data is shown in Figure 5.2 as well as in Appendix B.[4]

Descriptive statistics for this data are presented in Table 5.1. On average the monthly imports of EU and U.S. wheat have been very similar, imports of U.S. wheat being just 1.7 percent larger. However, considerable variation between different months has occurred. Likewise, prices have been very close to each other. The average price for EU wheat has been somewhat higher than the average U.S. wheat price (1.3 percent higher). Furthermore, the correlation between these two prices has been high (0.88) supporting the fact that exporting firms as well as governments of exporting countries follow closely each others moves in this market.

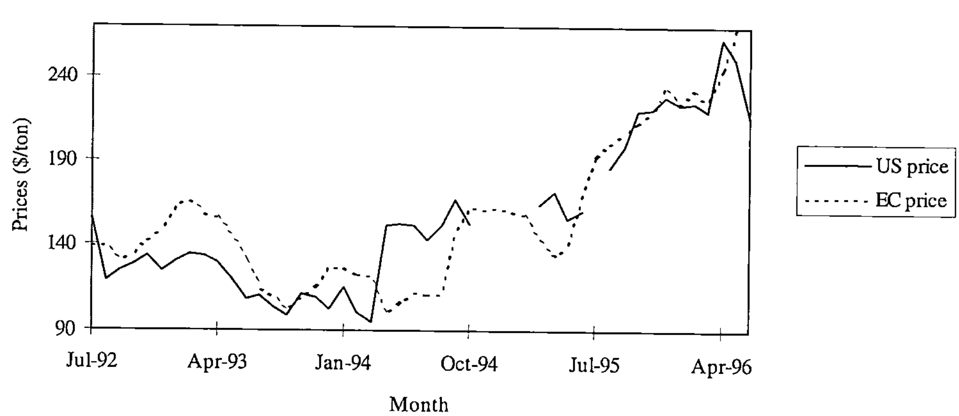


*Figure 5.2. Monthly Prices Paid by Morocco for EU and U.S. Wheat.*

[3] Wheat, corn, sorghum and soybeans.

[4] Note that U.S. prices for five months out of the 47 months in our sample are not available. This is because no average fob price and/or freight rate information were available for those months.

*Table 5.1. Descriptive Statistics for the Data Used in the Analysis.*

| Variable | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|
| Imports of U.S. wheat (1000 tons) | 88.598 | 74.378 | 0.0000 | 274.41 |
| Imports of EU wheat (1000 tons) | 87.118 | 72.362 | 0.0000 | 217.96 |
| Import price of U.S. wheat (US$/ton) | 153.36 | 45.998 | 94.891 | 263.00 |
| Import price of EU wheat (US$/ton) | 155.36 | 45.853 | 99.250 | 268.58 |

## 5.2. Estimation Methodology

The use of monthly instead of annual data has an effect on which estimation method to employ. When working with annual data a researcher very seldom has to deal with zero values of imports (the dependent variable). However, with monthly data it is quite common to have months in which no imports were made from a particular source. By looking at wheat import data for Morocco (in Appendix B), it can be seen that during 11 out of 47 months no U.S. wheat was imported to Morocco. For 8 months, EU wheat imports were zero.

This type of data is called censored data (i.e., data that is limited to nonnegative values) (Greene 1993). The distortion in the data results from the fact that during several months Morocco did not purchase any wheat from either the EU or the U.S. A possible explanation for imports of EU and U.S. wheats not being positive in every month, is that purchases by Morocco are not made until the "desire" to buy the wheat in question exceeds a certain level. However, we cannot observe desires, only import volumes, and those are nonzero only if the wheats are purchased. Negative imports, corresponding to various levels of desire below the threshold level, cannot be observed, and all months with no purchases are recorded as showing zero imports. No distinction is made between months during which Morocco was very close to buying the particular wheat in question and those during which it had very little desire to do so. This type of data calls for the use of a Tobit model.

Tobit models refer to regression models in which the range of the dependent variable is constrained in some way. In economics, such a model was first suggested in a pioneering work by Tobin (1958). He analyzed household expenditure on durable goods using a regression model which specifically took account of the fact that expenditure (the dependent variable of his regression model) cannot be negative. Tobin called his model the "model of limited dependent variables". Because he related his study to the literature on probit analysis, it, and its various generalizations, are known popularly among economists as Tobit models. These models are also known as censored regression models.

In general, we can formulate such a censored regression model as

$$y_t = \begin{cases} \mathbf{x}_t{}'\beta + u_t, & \text{if} \quad \mathbf{x}_t{}'\beta + u_t > 0 \\ 0 & \text{otherwise} \end{cases} \tag{5.3}$$

where $y_t$ is limited dependent variable, $\mathbf{x}_t$ is a set of explanatory variables and $u_t \sim N(0, \sigma^2)$ is the error term. The use of ordinary least squares (OLS) for such models results in biased and inconsistent estimates.

To see the problem of using OLS with truncated data i.e., ignoring the zero observations, we write out the expectation of the observed values of $y_t$ conditional on the fact that $y_t > 0$:

$$E[y_t | y_t > 0] = \mathbf{x}_t{}'\beta + E(u_t | y_t > 0). \tag{5.4}$$

If the conditional expectation of the error term is zero, there is no problem and OLS provides an unbiased estimator for $\beta$. Unfortunately, this is not the case. If the $u_t$ are independent and normally distributed random variables, with mean zero and variance $\sigma^2$, then the mean of the truncated error term is

$$E[u_t | y_t > 0] = E\left(u_t | u_t > -\mathbf{x}_t{}'\beta\right) = \sigma\lambda_t, \tag{5.5}$$

where $\lambda_t = \phi\left(\mathbf{x}_t{}'\beta/\sigma\right) / \Phi\left(\mathbf{x}_t{}'\beta/\sigma\right)$ is so called inverse Mills ratio (Greene 1993), and $\phi(\cdot)$ and $\Phi(\cdot)$ are the standard normal probability density function and cumulative distribution function evaluated at $\left(\mathbf{x}_t{}'\beta/\sigma\right)$. Consequently, the regression function can be written

$$E[y_t | y_t > 0] = \mathbf{x}_t{}'\beta + \sigma\lambda_t + \varepsilon_t. \tag{5.6}$$

The problem with OLS is that it omits the second term on the right-hand side of (5.6), leading to the inconsistent and biased estimator of $\beta$. It can also be shown that applying OLS to all observations (including the zero observations) is an unsatisfactory procedure and does not lead to a consistent estimator of $\beta$ (Judge et al. 1988).

To estimate the parameter values for our import demand function consistently we need to apply a censored-regression model which takes into account the censored sample problem. It is possible to estimate models of this type by maximum likelihood methods, but this approach is often quite cumbersome. A number of consistent alternatives to maximum likelihood estimation have been proposed. A procedure due to Heckman (1979) has been the most commonly used (e.g. Heien and Wessels 1990, Byrne et al. 1996). A modified Heckman's two-step approach is adopted in this study, as well.[5]

The estimation procedure of the traditional single equation Heckman approach involves two steps for the treatment of sample selection bias of the OLS estimation. Heckman correctly defines this bias as an omitted variable (or specification error) problem and shows that it is possible to estimate the variable ($\lambda_t$) that OLS estimation procedure omits. This is done in the first step of the Heckman procedure by utilizing a probit model, where the dependent variable is one or zero depending on whether $y_t$ is positive or zero. This provides a consistent estimator of $\beta / \sigma$, which can be used to provide a consistent estimator of $\mathbf{x}_t{}' \beta/\sigma$ and the inverse Mills ratio. Then, in the second step of the two-step procedure the consistent estimator of $\lambda_t$ is inserted into equation (5.6) in place of $\lambda_t$ and least squares estimation is applied to that equation. The parameter value estimates produced by this process are consistent and asymptotically normally distributed.

The traditional Heckman two-step method omits zero observations of the dependent variable for the second step. Amemiya (1974) generalized the Heckman approach to include all observations in the second step by developing a measure of the inverse Mills ratio for the zero observations, that is, $\lambda_t = \phi\left(\mathbf{x}_t{}'\beta/\sigma\right) / \left(1-\Phi\left(\mathbf{x}_t{}'\beta/\sigma\right)\right)$. Lee (1978) further extended the Amemiya two-step censored regression model to a simultaneous-equation model. Heien and Wessels (1990) applied this approach using all the observations at both steps to estimate a system of equations for a group of food commodities. Our application is similar to the Heien and Wessels approach.

In the first stage of our estimation procedure the decision to import (or not to import) is modeled as a dichotomous choice problem

(5.7) $$Y_t^i = f\left(P_t^i, P_t^k, M_{t-1}^i, M_{t-1}^k\right) \quad \forall t,$$

[5] Note that the modified Heckman's two-step approach as an estimation procedure has not been without criticism either. For example, Arndt et al. (1997) argue that while the modified Heckman's two-step estimator treats econometric problems associated with censored dependent variables, it is not fully consistent with economic theory. They claim that this technique may yield biased parameter estimates because the estimator relies upon market prices instead of reservation prices for non-consumed goods.

where $Y_t^i$ is 1 if imports of exporting country $i$'s wheat are positive and 0 if Morocco does not import that wheat. This probit equation, that determines the probability that Morocco will buy exporting country $i$'s wheat, is estimated by maximum-likelihood estimation. Using the parameter estimates of the probit model, the inverse Mills ratio is calculated.

The inverse Mills ratio for each wheat is then used as a regressor in the second stage regression. Therefore, the import demand functions to be estimated are

$$
(5.8) \quad \begin{aligned} M_t^{US} &= z^{US} + b^{US} P_t^{US} + b^{US} \eta^{US} M_{t-1}^{US} + e^{US} P_t^{EU} + e^{US} \eta^{EU} M_{t-1}^{EU} + v^{US} \lambda_t^{US} + \varepsilon_t^{US} \\ M_t^{EU} &= z^{EU} + b^{EU} P_t^{EU} + b^{EU} \eta^{EU} M_{t-1}^{EU} + e^{EU} P_t^{US} + e^{EU} \eta^{US} M_{t-1}^{US} + v^{EU} \lambda_t^{EU} + \varepsilon_t^{EU} . \end{aligned}
$$

The restriction from economic theory imposed on this system of equations is that cross-price effects across equations are restricted to be the same (i.e., $e^{US} = e^{EU}$).

The disturbances in these two equations at a given time (i.e., $\varepsilon_t^{US}$, $\varepsilon_t^{EU}$) are likely to reflect some common unmeasurable or omitted factors, and hence could be correlated. When this contemporaneous correlation exists, the appropriate joint estimation technique is seemingly unrelated regression estimation (SUR). In addition, it is clear that the equations in (5.8) are intrinsically nonlinear in their coefficients. Therefore, in the second step these import demand equations are estimated as a system of nonlinear seemingly unrelated regression (NSUR) equations, each having the same set of regressors, except for the inverse Mills ratios, that differ by commodity.

## 5.3. Estimates of the Import Demand Functions

The remainder of this chapter discusses the empirical results achieved using the two-step estimation process described above implemented using the SHAZAM econometrics package. The parameter estimates for import demand equations (5.8) are shown in Table 5.2. For comparison, the demand system was also estimated by NSUR when the inverse Mills ratios are not included (that is, ignoring the censored sample problem). These parameter estimates are given in the last two columns of Table 5.2.[6] The price elasticities are also shown in Table 5.2.

[6] NSUR estimation was conducted by using both the data consisting of only positive import observations and the data which included the zero observation as well. Only the results of NSUR that did not include zero observations are provided in Table 5.2.

*Table 5.2. Censored-regression Method and Uncensored-regression Method Parameter Estimates of the Moroccan Import Demand System.*

| Parameter | Censored-regression method* U.S. Wheat | Censored-regression method* EU Wheat | Uncensored-regression method** U.S. Wheat | Uncensored-regression method** EU Wheat |
|---|---|---|---|---|
| Intercept | 1.6388 (4.2175) | 1.2916 (4.0066) | 1.0661 (2.9556) | 1.9923 (4.3198) |
| $b^{US}$ | -1.3274 (3.2714) | - | -0.9838 (1.7121) | - |
| $b^{EU}$ | - | -0.90633 (2.6246) | - | -1.0713 (1.8647) |
| $e^{US}$ | 0.81646 (2.2552) | - | 0.6566 (1.2619) | - |
| $e^{EU}$ | - | 0.81646 (2.2552) | - | 0.6566 (1.2619) |
| $\eta^{US}$ | 0.35373 (1.9532) | 0.35373 (1.9532) | 0.5127 (1.2677) | 0.5127 (1.2677) |
| $\eta^{EU}$ | 0.26385 (1.4300) | 0.26385 (1.4300) | 0.0709 (0.4357) | 0.0709 (0.4357) |
| $v^{US}$ | -0.70446 (3.3988) | - | - | - |
| $v^{EU}$ | - | -0.86685 (3.1649) | - | - |
| $R^2$ | 0.6169 | 0.3127 | 0.5359 | 0.2740 |
| Own-price elasticity at means | -2.29781 | -1.61625 | -1.49712 | -1.62876 |
| Cross-price elasticity at means | 1.43167 | 1.43730 | 1.04396 | 0.95527 |

* Heckman procedure for a system of import demand equations.
**Nonlinear SUR procedure for a system of import demand equations.
Note: The numbers in parentheses below the coefficients are the *t* ratios. *t* ratios of 1.645 or larger indicate that an estimate is significant at 10 percent level. Therefore, the only estimate in the censored regression model that is not significant at the 10 percent level is $\eta^{EU}$.

The inverse Mills ratios are significant for each import demand equation, indicating that inconsistent estimates would have resulted if the import demand equations had been estimated without taking into account the decision to import (or not import) wheat from each exporting country. The comparison between the two estimation techniques also shows that with the censored model we get an improvement in the goodness of fit statistic, $R^2$.

In the censored model, own-price elasticities as well as cross-price elasticities are clearly elastic. In comparison, price elasticities of the uncensored model are less elastic, with the only exception being the own-price elasticity for the EU[7]. The elasticity results of the censored-regression model seem plausible even though numerous previous studies, reviewed by Gardiner and Dixit (1986), have shown that short-run import demand elasticities for U.S. wheat have been inelastic, with the average estimate being around 0.6-0.7.[8] One reason for our differing results is that our study uses monthly data instead of annual (sometimes quarterly) data commonly used in previous studies.

The importing country's wheat imports, controlled often by parastatal agency, are usually planned for one crop year at a time. Needs of wheat imports for a year are calculated and then this required amount of wheat is imported at some time during the year. In the estimation with annual data, each import volume observation corresponds to a planned (needed) amount that the parastatal agency has to import that crop year, despite the fact that average price of the imported wheat for the year might be unusually high. Therefore, inelastic price elasticity estimates with annual data are not surprising.

Within each year, the parastatal agency tries to import the planned total amount of wheat as economically as possible. Weekly and monthly prices may have large impacts on when wheat import transactions are made during each year. The use of monthly data allows us to capture better this more price sensitive behavior of the importing country. Thus, much more elastic price elasticity estimates were expected.

All the parameter estimates of import demand equations have correct signs in the censored-regression model. The own-price effect on U.S. wheat imports is greater than the own-price effect on imports of EU wheat, meaning that Morocco responds more strongly to U.S. price changes than to EU price changes. Although EU wheat and U.S. wheat are differentiated products, the large cross-price effects illustrate the close substitutability between these two wheats.

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[7] An even bigger contrast between the elasticity results occur when censored-regression model is compared to uncensored model which uses zero observations as well. Own-price elasticities of this uncensored model are very inelastic and the elasticity for EU wheat is incorrectly signed. Furthermore, cross-price elasticities are nearly perfectly inelastic.

[8] In their estimation of import demand elasticities previous studies used a variety of methods, which included direct econometric estimation and analytical methods like Delphi method. Although differing methods yielded substantially different results, almost all of them resulted in inelastic price elasticities. See Abbott (1988) for more on econometric and economic issues related to estimation of agricultural import demand elasticities.

Economic theory demands that the cross-price effects across equations are equal. The null hypothesis $H_0$: $e^{US} = e^{EU} (= e)$ was tested and could not be rejected. This cross-price effect is smaller than both own-price effects. Therefore, another restriction of economic theory is satisfied: $b^{US}b^{EU} - e^2 > 0$. Finally, marginal switching cost parameters, $\eta^{US}$ and $\eta^{EU}$, are small relative to own- and cross-price coefficients as expected.

When switching from the uncensored-regression method to the censored-regression method, considerable improvement occurs in the significance levels of parameter estimates. In the censored model, all but one parameter estimate are clearly significant at the 10 percent level. The parameter which is not quite significant at the 10 percent level is $\eta^{EU}$.

One reason for this result may be the data used in the estimation. For U.S. wheat exports to Morocco, the *World Grain Statistics* data were combined with detailed EEP-bonus data (distinguishing export subsidies to Morocco) when the import prices paid by Morocco were derived. On the other hand, for EU wheat exports to Morocco no additional information was used (i.e., we do not know Morocco specific export restitutions). *World Grain Statistics* data provides an fob export price for EU wheat (net of export refunds) that is the average price to all destinations. This data deficiency on the EU side may be related to the fact that, in general, significance levels of the parameter estimates for the import demand equation for EU wheat are consistently lower than significance levels of the parameter estimates for the import demand equation for U.S. wheat. This data deficiency might also help to explain the lower $R^2$ for the EU wheat equation.

Finally, Chapter IV presented a new agricultural trade modeling approach in which the theory of switching costs was added to the conceptual framework. In the light of the above econometric parameter estimates, the inclusion of switching cost parameters into the empirical model of the Moroccan wheat import market appears to be valid. The switching cost parameter estimates also suggest that costs of switching away from U.S. wheat are larger than costs of switching away from EU wheat, meaning that somehow U.S. is able to lock in Morocco more tightly to itself than the EU is able to do. This result is consistent with Wilson et al. (1987), who found that the U.S. as an wheat exporter seems to enjoy greater brand loyalty than the EEC.

## 5.4. Conclusions

This chapter presents the econometrically estimated Moroccan import demand equations for EU and U.S. wheat. The method used to obtain the parameter estimates of the import demand equations is a censored-regression estimation method. Existence of months with zero import volumes (the dependent variable) in the data make it necessary to use the censored model. Comparison of the censored and uncensored models shows that considerable improvement in the estimation results are obtained when the censored-regression method is used. In particular, the method used is the modified Heckman's two-step method applied in a fashion similar to Heien and Wessels (1990).

The estimation results are consistent with the restrictions that the conceptual framework developed in Chapter IV imposes on the import demand functions. The signs of the parameter estimates are as expected and statistical significance levels of these estimates are generally good.

A comparison of the own-price and cross-price elasticities calculated in this study with those of previous studies indicate some differences. Not surprisingly, more elastic estimates are found in this study than in the previous work. One important reason for this outcome is that this study uses monthly data instead of the more commonly used annual data. Import volumes of wheat needed for each crop year are planned ahead of time and a parastatal agency must import the required amount, despite the fact that average price of the imported wheat for the year might be unusually high. Therefore, relatively inelastic price elasticity estimates with annual data are not surprising.

However, within each year the parastatal agency attempts to import the planned total amount of wheat as economically as possible. Therefore, weekly and monthly prices have a large impact on when wheat import transactions are made during each year. More elastic price elasticity estimates resulted in this study, because the monthly data reflected this more price sensitive behavior of the importing country.

Finally, econometric estimations of this chapter support our new agricultural trade modeling approach in which impacts of switching costs are taken into account.

# CHAPTER VI

# EMPIRICAL MODEL SOLUTIONS

The purpose of this chapter is to illustrate how the model developed in the preceding chapters can be used to analyze export policies of governments as well as price setting behavior of exporting firms when strategic interaction among players and switching costs between goods in the market are present. To accomplish this task, several analyses are performed and results are compared to a base solution (which corresponds roughly to the pre-GATT situation). The scenarios are divided in three broad groups.

The first group analyzes the effects that changes in key parameter values have on the behaviors of exporting firms and exporting countries. In particular, effects of switching costs and of opportunity costs of public funds are studied. In addition, effects of different degrees of product differentiation, of different marginal costs and of asymmetries in parameter values are analyzed.

The second group of scenarios illustrates how alternative institutional arrangements (game structures) at the country level change the levels of export subsidies (or taxes), prices, export volumes, and the payoffs for four players: the European Union, the United States, the EU wheat exporting firm, and the U.S. wheat exporting firm. A free trade scenario and the outcomes when either EU or U.S. unilaterally reforms by eliminating its export subsidies are considered. Collusive behavior by EU and U.S. governments is also examined. Two issues are examined regarding the Uruguay Round GATT agreement. The first looks at the effects of the final GATT outcome by imposing subsidy expenditure limits. The second issue analyzes how the welfare effects of new GATT agreement differ when effects of CAP reform are taken into account.

In the last group of scenarios alternative firm behaviors are examined to illustrate effects that different levels of firm market power have on the market outcomes. A cartel of exporting firms when governments are subsidizing is examined, as well as the case in which firms are perfectly competitive. In addition, timing in players' decisions affects the degree of market power that each player has. Two scenarios, one in which exporting firms are the first movers, and another one in which exporting firms and exporting countries' governments set their strategies simultaneously, are presented to study effects of playing order.

The chapter begins with general discussion of the structure of the empirical model. Then the solution technique for the model is explained. The base solution is shown next and it is compared with actual trade data. Thereafter, the results of the different scenarios described above are presented and discussed.

## 6.1. Model Structure

This section briefly presents some additional elements of the model structure not mentioned in the previous chapters. The four major players in the model are the government of European Union, the government of the United States, an aggregate firm exporting EU wheat and an aggregate firm exporting U.S. wheat. The importing country is Morocco.

It is important to keep in mind that this model is a so called third-market model in which exporting countries (the EU and U.S.) and their exporting firms compete only in a single third market (Morocco). This simplification is useful to allow the strategic effects of certain policy shocks to be seen in pure form. However, domestic wheat production, stocks and consumption of exporting countries are not included in the model. So, one way to describe the settings under which the model operates is based on the surplus disposal concept. That is, both exporting countries hold very large amounts of wheat that needs to be either exported or stored, and magnitudes of wheat exported to one importing country do not provide much of relief to the overall pressure to export. So, under these circumstances, when the government of each exporting country is awarding export subsidies to enhance wheat exports to the importing country, one reasonable form of its objective function would seem to be to maximize export revenues less costs of export subsidies. However, when impacts of policy shocks that may cause considerable changes in domestic production, stocks and/ or consumption of exporting countries are analyzed, welfare effects of the model should be analyzed with care since those changes in domestic production, stocks and consumption are not captured by the model.

In reality, more than one exporting firm operates in each exporting country. However, it is reasonable to assume that marginal costs (producer price + transportation costs) within each country are constant and equal across wheat exporting firms. This very common assumption of constant marginal costs makes it possible to aggregate across exporting firms to represent the industry behavior with an aggregate firm, i.e. industry output is the sum of individual outputs (Appelbaum 1982). Thus, an aggregate exporting firm is used to represent industry behavior in each exporting country. McNally (1993) states that constant marginal costs also imply that exporting firms are price takers when buying wheat. This is in agreement with real market behavior. There are many buyers of domestic wheat in both the EU and U.S., making the domestic market structure very close to perfect competition on the buying side, while on the export selling side there are relatively few international sellers that may have some market power.

However, one recognized caveat of this aggregate firm approach is that the exporting firm stage is described as a duopoly, which assigns too much monopoly power to the firms, leading to higher prices. The reason for retaining the duopoly assumption is that an introduction of several exporting firms would substantially complicate the model structure, and could make it intractable. Effects of assigning too much market power to the firms are discussed in the base solution section as well as in the section that examines different firm behaviors.

The only differences between the theoretical model described in Chapter IV and the empirical model used in this chapter exist in the presentation of import demand. Due to data limitations, estimated import demand functions used in the empirical model have somewhat different forms compared to theoretical import demand function.[1]

Determination of simulation solutions for our empirical international wheat trade models requires setting values of model parameters. In Chapter V parameter values of import demand functions were estimated. In addition to these parameters another set of parameters need to be established.

The monthly U.S. domestic farm price for winter wheat, as given by the USDA-NASS electronic database, is used as a basis for deriving the marginal cost parameter for the U.S. exporting firm $\left(C_t^{US}\right)$. To get a proxy for the marginal cost in Morocco, monthly freight rates for the route U.S. Gulf-Casablanca, as given by *World Grain Statistics*, are added to the domestic U.S. farm price. If the cost of moving wheat from interior locations to U.S. Gulf export facilities is low relative to the value of the wheat and remains fixed within a month, then it might be argued that a domestic farm price plus a freight rate may approximate marginal cost for the U.S. wheat exporting firm. Similarly, the marginal cost of the EU wheat exporting firm, $\left(C_t^{EU}\right)$, is proxied by a combination of a producer selling price and a freight rate. The EU farm selling prices of wheat were obtained from Eurostat's *Agricultural Prices 5b* publication and freight rates for the route EU-Casablanca were taken from *World Grain Statistics*. Marginal costs from July 1992 to May 1996 are shown in Appendix B.

The parameter representing the opportunity cost of public funds in the U.S., $\mu^{US}$, is drawn from the public finance literature. Ballard et al. (1985) showed that an additional dollar to the U.S. government (to be used to finance export subsidies, for example) causes a deadweight loss in the range of 17 to 56 cents, with the exact value depending on the labor supply and saving elasticities. In most of our simulations we use what they suggested to be a reasonable mean estimate of the opportunity cost of public funds in the U.S. economy, that is $\mu^{US} = 1.332$. This says that additional welfare cost of public funds is 33.2 percent.

[1] This modification was already discussed in detail in Chapter V and therefore will not be repeated here.

Corresponding studies for the EU on marginal welfare costs of taxation do not exist. However, Ballard et al. mention that the opportunity cost of public funds is likely to be higher in countries where tax levels are higher. Since tax rates are in general higher in EU countries than they are in the U.S., we should expect $\mu^{EU}$ to be at least as large as $\mu^{US}$. Without better knowledge of the EU side, we assume in the base case that $\mu^{US} = \mu^{EU}$.

Finally, the value of discount factor parameter $\delta$ used by both exporting firms and governments is 0.99, implying an annual interest rate of about 12.8 percent.[2]

## 6.2. Solution Technique

In our finite period dynamic model of international wheat trade, governments of exporting countries in each period set export subsidies to maximize their discounted future welfare given the history of the game and expected behavior of the firms and the importing country in the future. Then in each period the exporting firms set their prices to maximize discounted future profits given government subsidies and the history of the game. Because of switching costs, the importing country's behavior depends on history, in particular on previous purchases of the good from a specific country. Therefore, governments' and firms' decisions in one period also have (predictable) effects into the future.

Since in each period the optimal actions of governments' and firms' (players) are affected by all future optimal actions, we need to know what those future actions will be. The reason for examining a finite period model is that we need to have a terminal period in which we can determine the optimal final actions of players as linear functions of state. Note that when the finite number of periods modeled is large, the effect of excluded future periods becomes minuscule through discounting. By backward induction we then determine the optimal actions of players as functions of state for all remaining future periods.

In Chapter IV the algebra of the multiperiod model representing this decision process is explained. Equations (4.51)-(4.55) give us the equilibrium export subsidies (taxes if negative), prices, export volumes, governments' welfares, and firms' profits as functions of state for every time period $t$.

In order to compute the Markov perfect equilibrium of the empirical model we first need to solve for the values of the parameters for equations (4.47), (4.48), and (4.51)-(4.55) in each period given the current state. To do this, we start in the final period $T$. In the final period values of the parameters can be stated as functions of estimated parameters of the import demand functions, of marginal costs, and of the opportunity cost of public funds, all of which are assumed known. Knowing values of the parameters in equations (4.47), (4.48),

[2] The following simulation results are largely insensitive to different values of the discount rate.

and (4.51)-(4.55), when $t = T$, we move to the period $T$-$1$. In a manner similar to the final period, we can write values of period $T$-$1$ parameters as functions of parameters of the import demand functions, of marginal costs, of opportunity cost of public funds, of discount factor, and of now known final ($T$) period parameters. This procedure can be repeated for all the remaining $T$-$2$ (earlier) periods to determine the values of parameters $A_t^{in}$, $B_t^{in}$, $D_t^{im}$, $E_t^{ij}$, $G_t^{ij}$, $H_t^{ij}$, and $K_t^{im}$ ($j = 1,2,3$, $m = 1,2,3,4$, and $n = 1,2,3,4,5$) in each period. Now equations (4.51)-(4.55) are determined as function of current state only.

After we have determined players' optimal actions as functions of state for all the time periods, we can calculate the equilibrium solutions of our model by solving forward one period at a time. Note that as we solved for players' optimal actions as functions of state, the states for periods 2 to $T$ were unknown. However, in the first period governments' (initial) state, that is export volumes at period 0, are given by data. Therefore, starting from the first period, the equilibrium values for export subsidies, prices, export volumes, firms' profits, and governments' welfares can be easily determined because they are functions of already determined parameters and the initial state. Then we can move forward to period 2 and solve for the equilibrium because we now have required information on the values of different parameters and on the current state (i.e., on the previous period export volumes). This same procedure is then repeated one period at a time for all of the remaining time periods to achieve the Markov perfect equilibrium of this dynamic international wheat trade model. The code that implements the above procedure can be found in Appendix C.

## 6.3. Base Solution

This section analyzes base solutions of the empirical model. Since switching costs imply the decision making process is dynamic in nature, the section first examines the dynamics of the model (that is, how players' actions change during the studied time horizon). After that the model's base solutions are compared with actual data.

In order to better see the dynamics of the model, marginal costs of each exporting firm are held constant through time. The fixed marginal costs are \$130 per ton for the U.S. wheat exporting firm and \$190 per ton for the EU wheat exporting firm. The initial period export volumes are taken from historical data. Initial U.S. wheat exports are 89,000 tons and initial EU wheat exports are 87,000 tons.

The results for time horizon of 21 time periods are shown in Table 6.1. In the middle periods, the model converges to its steady state. At the beginning and at the end of the time horizon, familiar effects from the two-period model of switching costs arise. At the beginning, the EU side, with more than its steady-state share of the Moroccan wheat market, subsidizes its exports less and sells at

*Table 6.1. Base Solution of the Empirical Model When Marginal Costs are Held Constant Over Time.*

| time | U.S. Exports metric tons | EU Exports metric tons | U.S. Price $/ton | EU Price $/ton | U.S. Subsidy $/ton | EU Subsidy $/ton |
|---|---|---|---|---|---|---|
| 1 | 130223.5 | 84316.3 | 156.45 | 185.17 | 39.33 | 77.05 |
| 2 | 120838.0 | 82423.2 | 143.85 | 181.15 | 45.16 | 78.90 |
| 3 | 134951.3 | 82419.1 | 162.76 | 181.43 | 36.41 | 78.78 |
| 4 | 136947.0 | 81734.3 | 165.42 | 180.09 | 35.18 | 79.41 |
| 5 | 137253.9 | 81588.9 | 165.83 | 179.80 | 34.99 | 79.54 |
| 6 | 137302.5 | 81563.6 | 165.89 | 179.75 | 34.96 | 79.57 |
| 7 | 137310.3 | 81559.5 | 165.90 | 179.74 | 34.95 | 79.57 |
| 8 | 137311.6 | 81558.8 | 165.90 | 179.74 | 34.95 | 79.57 |
| 9 | 137311.8 | 81558.7 | 165.90 | 179.74 | 34.95 | 79.57 |
| 10 | 137311.8 | 81558.7 | 165.90 | 179.74 | 34.95 | 79.57 |
| 11 | 137311.8 | 81558.7 | 165.90 | 179.74 | 34.95 | 79.57 |
| 12 | 137311.8 | 81558.7 | 165.90 | 179.74 | 34.95 | 79.57 |
| 13 | 137311.8 | 81558.7 | 165.90 | 179.74 | 34.95 | 79.57 |
| 14 | 137311.6 | 81558.8 | 165.90 | 179.74 | 34.95 | 79.57 |
| 15 | 137310.8 | 81559.3 | 165.91 | 179.74 | 34.95 | 79.57 |
| 16 | 137307.2 | 81561.6 | 165.91 | 179.74 | 34.95 | 79.57 |
| 17 | 137290.1 | 81571.1 | 165.92 | 179.74 | 34.95 | 79.57 |
| 18 | 137204.8 | 81611.0 | 166.00 | 179.78 | 34.91 | 79.55 |
| 19 | 136753.4 | 81761.1 | 166.50 | 180.10 | 34.69 | 79.39 |
| 20 | 134173.4 | 82130.8 | 170.14 | 183.15 | 33.28 | 78.20 |
| 21 | 118084.8 | 79902.6 | 199.80 | 213.25 | 19.16 | 64.91 |

higher price to exploit its current market share. Thus, the EU is losing market share, but it sells more than its steady-state exports until converging to steady state. In contrast, the U.S. exporting firm and government first behave more aggressively in order to gain more market share that can be exploited later on. The U.S. government awards higher export subsidies than the steady-state subsidy level and the U.S. exporting firm charges a lower price than in the steady state until converging to steady state.

During last periods of the dynamic game the "second-period effect" of the two-period model can be recognized. The exporting countries become relatively more interested in exploiting their current market share and less interested in increasing their market share. Therefore, both exporting countries monotonically decrease their export subsidies while exporting firms increase their prices.

The steady state describes the most common situation occurring in the real world. In every steady-state period the government and the exporting firm of each exporting country must balance between two incentives. The first incentive is for the government to subsidize a small amount and for the firm to charge a high price in order to exploit their current market share. This is balanced against the incentive to award a high export subsidy and set a low current price in order to build up current market share and so increase the government's future welfare and the firm's future profits. Later in this chapter we analyze more impacts of switching costs on the model's solutions.

The second purpose of this section is to compare the model's results with actual data. To do this observed marginal costs that vary from month to month are used, instead of fixed marginal costs that were used when the dynamics of the model was studied. The presented base solution of the model is for the period July 1992 through June 1993, reflecting the situation before CAP reform and the Uruguay Round GATT agreement.[3] Alternative base scenarios are also discussed. Table 6.2 shows average monthly results of the base solution for export volumes, prices, and export subsidies together with corresponding averages of actual data. Comparisons to alternative scenarios are also presented in this table.

In general, the model's base solution is reasonably consistent with actual data. On average the United States has been a larger wheat exporter to Morocco than the European Union. The price of exported U.S. wheat has been somewhat lower than the price of EU wheat. One reason for differing prices is that EU

*Table 6.2. Comparison of Actual Values Versus Model Solutions for Average Monthly Export Volumes, Prices, and Export Subsidies During Time Period July 1992 through June 1993.*

| U.S. Exports | EU Exports 1000 tons | U.S. Exports 1000 tons | EU price US$/ton | U.S. price US$/ton | EU subsidy US$/ton | U.S. subsidy US$/ton |
|---|---|---|---|---|---|---|
| Actual | 141 | 79 | 126 | 146 | 31 | 108 |
| Base Solution | 139 | 79 | 169 | 184 | 39 | 111 |
| Perfectly* Competitive Firms | 182 | 81 | 107 | 113 | 29 | 116 |
| Ex Post** | 101 | 66 | 238 | 270 | 476 | 562 |

* This is an alternative scenario in which exporting firms have no market power. They are perfectly competitive, setting their prices equal to their marginal costs.

**This is an alternative scenario in which timing in decisions have reverse order. Exporting firms set their prices before governments make their decisions on how much to subsidize those exports.

[3] CAP reform was agreed upon in 1992, but the reform measures did not become effective before July 1, 1993, the start of the marketing year 1993/94 (Toepfer 1995).

wheat and U.S. wheat are differentiated products. Positive export subsidies are used by both exporting countries' governments. Furthermore, considerably higher export subsidies have been used to export EU wheat than U.S. wheat, since on average internal wheat support prices in the EU have been higher than in the U.S.

The model's predictions of export volumes are quite good. The predicted level of average EU export volume to Morocco fits almost exactly to the observed value with error of only 0.06 percent (51 tons). The prediction error for average U.S. wheat exports is larger, but still very small. The model predicts average U.S. exports as 139 thousand tons, when it is actually 141 thousand tons (underestimated by 2 percent). Average export subsidies predicted by the model overestimate observed average export subsidies. In the case of U.S. the actual average export subsidy is approximately $31 per ton. However, the model predicts a higher $39 per ton subsidy. Similarly, the model overestimates the average export subsidy on EU wheat. The error in this case is 3 percent ($3 per ton).[4]

The empirical model does not perform as well at predicting prices paid by Morocco. The model's prediction of the average price paid by Morocco on U.S. wheat is 34 percent ($43 per ton) higher than the observed average price, and the price of the EU wheat is overestimated by 26 percent ($38 per ton). However, this result is not surprising and can be explained by the assumption that the model makes on firm level competition. The model assumes that one exporting firm exports wheat from each exporting country. That is, a duopoly structure is assumed at the firm stage of each period. In reality, it is more than one firm that exports EU wheat as well as U.S. wheat. Therefore, the base solution exaggerates the level of market power that exporting firms have, implying higher prices and somewhat smaller (or about the same) export volumes than what we observe in actual data.

This issue of firm level market power can be further examined with the case where firms are perfectly competitive (price takers) and set their prices equal to their marginal cost. Table 6.2 shows average monthly results of this scenario for export volumes, prices, and export subsidies.

In the absence of firm level monopoly power prices paid by Morocco are much lower than in the base solution and trade volumes have increased. What is more interesting is that prices are also lower than the observed prices, and

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[4] Naturally, the base solution is unable to fully capture observed behavior. It is important to keep in mind that this is not a calibration model. Therefore, the base solution should not be confused with the so called benchmarking in which a model is calibrated such that it reproduces exactly the actual data. Our model uses econometrically estimated parameter values, resulting in values of endogenous variables that are reasonably close, but should not be expected to exactly match observed values of those variables.

export volumes are larger than actual exports of EU and U.S. wheat. Therefore, these results suggest that international wheat exporting firms are not just price takers in the Moroccan wheat market. On the other hand, the level of market power that they exercise is not as high as in the duopoly structure of the base solution. However, an introduction of several exporting firms would substantially complicate the model structure, and could make it intractable. Therefore, the duopoly assumption is retained even though it exaggerates the degree of firm market power.

Another matter that has impact on the firm level market power is timing in decisions. In our analysis so far, governments are assumed to move before firms in each period. However, the wheat export subsidy program in the U.S. and in the EU that allows firms to bid for export subsidies seems to suggest the reverse order. Exporting firms negotiate a price in the importing country first and then request a subsidy from the government. In this sense, the subsidy is given ex post. Since in this so called ex post game, firms are the first-movers (Stackelberg leaders in each period), they have even more market power than in the game where governments are the first-movers. With the duopoly assumption the results of this model are even further away from real world observations. The last row of Table 6.2 presents the results of the ex post game.

It is clear that the ex post model greatly exaggerates the level of market power that exporting firms have. The model suggests prices that are almost twice as high as the actual prices. Exports volumes are obviously lower than what is observed, and the levels of export subsidies that they extract from the governments are empirically unacceptable. Since the empirical model with ex ante (governments moving first) structure of the game performs much better (because it captures better the degree of monopoly power that exporting firms have in the Moroccan wheat market), we use it in our analyses instead of the ex post game. It is also important to notice that if the firms behave perfectly competitively, then the order of decisions becomes irrelevant since firms always set their prices equal to their marginal costs. In the latter part of this chapter we further analyze effects of alternative firm level behavior on the model's solutions.

### 6.3.1. Difficulties in Predicting Long Time Horizon Behavior

The model's results over a longer time horizon are studied next. Month-to-month results for the time period August 1992 through May 1996 are shown in Table 6.3. Effects of the MacSharry CAP reform on the base solution can be seen. During the first year after CAP reform (crop year 1993/94) EU support prices were cut almost by 20 percent. This reduction in support prices meant that lower per unit export subsidies for EU wheat exports were needed. The drop in the EU export subsidy level since July 1993 can be seen in Table 6.3.

*Table 6.3. Base Solution of the Empirical Model: August 1992 to May 1996.*

| month | U.S. Exports metric tons | EU Exports metric tons | U.S. Price $/ton | EU Price $/ton | U.S. Subsidy $/ton | EU Subsidy $/ton |
|---|---|---|---|---|---|---|
| Aug-92 | 131113.6 | 82210.1 | 158.15 | 189.03 | 41.45 | 99.50 |
| Sep-92 | 121531.5 | 79774.9 | 146.71 | 186.65 | 51.67 | 109.75 |
| Oct-92 | 135810.3 | 79286.3 | 166.32 | 187.18 | 44.50 | 114.20 |
| Nov-92 | 137989.5 | 78867.3 | 168.32 | 184.77 | 40.00 | 109.09 |
| Dec-92 | 138022.5 | 78283.1 | 169.93 | 186.05 | 44.39 | 116.93 |
| Jan-93 | 137832.2 | 78144.2 | 170.47 | 186.53 | 46.78 | 119.39 |
| Feb-93 | 137714.0 | 78169.7 | 170.57 | 186.61 | 48.86 | 119.15 |
| Mar-93 | 138541.3 | 77983.1 | 169.41 | 185.82 | 42.83 | 116.82 |
| Apr-93 | 139538.8 | 77086.9 | 169.38 | 186.47 | 39.02 | 124.67 |
| May-93 | 140303.9 | 76692.7 | 169.04 | 186.05 | 34.29 | 128.06 |
| Jun-93 | 140317.4 | 77841.5 | 167.54 | 183.08 | 25.49 | 118.91 |
| Jul-93 | 137460.9 | 83443.7 | 163.85 | 173.87 | 27.17 | 52.17 |
| Aug-93 | 136732.8 | 84118.2 | 163.04 | 174.78 | 28.04 | 49.25 |
| Sep-93 | 136569.9 | 83511.2 | 163.98 | 176.71 | 31.15 | 58.91 |
| Oct-93 | 136217.9 | 83171.9 | 165.04 | 177.93 | 34.70 | 65.24 |
| Nov-93 | 135317.2 | 83360.5 | 166.15 | 178.74 | 41.66 | 65.99 |
| Dec-93 | 134791.2 | 83155.2 | 167.03 | 180.10 | 48.24 | 69.26 |
| Jan-94 | 135717.5 | 81560.1 | 167.70 | 182.58 | 47.28 | 87.52 |
| Feb-94 | 136739.1 | 81162.0 | 166.91 | 181.59 | 40.95 | 86.69 |
| Mar-94 | 137428.4 | 80687.3 | 166.83 | 181.61 | 37.80 | 89.83 |
| Apr-94 | 137731.3 | 80491.4 | 166.86 | 181.51 | 37.15 | 89.96 |
| May-94 | 138224.8 | 79806.6 | 167.18 | 182.40 | 35.64 | 97.68 |
| Jun-94 | 138187.3 | 79849.4 | 167.35 | 182.17 | 35.61 | 99.66 |
| Jul-94 | 137697.4 | 81937.0 | 164.99 | 177.77 | 29.20 | 72.11 |
| Aug-94 | 136562.4 | 82377.0 | 166.06 | 178.95 | 36.35 | 71.95 |
| Sep-94 | 135474.1 | 81968.1 | 168.12 | 181.74 | 46.66 | 82.64 |
| Oct-94 | 134666.2 | 81534.6 | 169.76 | 183.93 | 55.58 | 92.25 |
| Nov-94 | 134705.3 | 81474.7 | 169.50 | 183.91 | 54.75 | 92.53 |
| Dec-94 | 134800.1 | 81430.8 | 169.42 | 183.86 | 54.46 | 92.35 |
| Jan-95 | 135084.1 | 81133.0 | 169.43 | 184.15 | 51.92 | 98.11 |
| Feb-95 | 134282.9 | 83091.0 | 167.90 | 180.44 | 51.16 | 72.42 |
| Mar-95 | 134244.5 | 82698.2 | 168.28 | 181.99 | 52.93 | 79.05 |
| Apr-95 | 134537.9 | 82142.6 | 168.62 | 182.82 | 52.13 | 84.09 |
| May-95 | 134286.0 | 81100.5 | 170.73 | 185.63 | 57.53 | 102.43 |
| Jun-95 | 132799.8 | 82750.2 | 170.64 | 183.54 | 61.19 | 87.36 |
| Jul-95 | 130564.2 | 84836.2 | 170.72 | 182.21 | 70.71 | 69.80 |
| Aug-95 | 129490.9 | 85751.5 | 170.35 | 182.13 | 73.71 | 62.90 |
| Sep-95 | 128744.6 | 85664.8 | 171.36 | 183.72 | 79.47 | 67.88 |
| Oct-95 | 128119.4 | 85367.6 | 172.61 | 185.39 | 85.98 | 74.60 |
| Nov-95 | 127934.1 | 85079.7 | 173.14 | 186.30 | 87.97 | 79.68 |
| Dec-95 | 127585.8 | 85269.9 | 173.37 | 186.29 | 90.72 | 78.10 |
| Jan-96 | 127828.8 | 85133.6 | 173.04 | 186.31 | 87.90 | 79.69 |
| Feb-96 | 127384.0 | 85530.2 | 173.28 | 185.96 | 89.71 | 76.13 |
| Mar-96 | 126683.2 | 85772.0 | 173.94 | 186.54 | 89.71 | 76.18 |
| Apr-96 | 123114.5 | 86257.0 | 178.98 | 190.83 | 98.14 | 76.83 |
| May-96 | 107490.1 | 83406.4 | 208.45 | 221.79 | 97.51 | 65.32 |

The problems with the model's predictions arise during the last two years of the horizon. This is best seen from export subsidy levels that the model predicts. Very high subsidy levels are predicted for both EU and U.S. wheat exports. However, this is far from the actual, quite extraordinary situation in the world wheat market that occurred during the crop years 1994/95 and 1995/96. Domestic consumption of wheat in the EU and the U.S. was growing faster than domestic production of wheat. Wheat stocks were decreasing fast, especially in the EU.[5] Therefore, the EU's (and U.S.'s) needs to export wheat surpluses were much smaller than before. Furthermore, some other major wheat exporting countries were experiencing below-normal harvests. Meanwhile, overall demand for grains continued to increase, reflecting robust economic growth in many countries, especially in Asia. The reduced supply and the strengthened demand in the international wheat market sharply increased the world market price of wheat. In fact, the world price of wheat increased so much that in 1995/96 the United States did not award any EEP bonuses for wheat exports. The EU even ended up taxing its wheat exports in the process of stabilizing domestic support prices.

One of the reasons why the empirical model was not able to capture this actual development in the market is because domestic wheat production, stocks and consumption of exporting countries are not explicitly included in our model. This means that, for example, effects of CAP reform on EU's domestic wheat production and consumption (and therefore, on exports) are not taken into consideration.

Another reason is the objective function chosen in this study. The objective function of each government is assumed to be total discounted future export revenues less the cost of subsidizing those exports. The objective functions are assumed to have this same structure in each time period. Opportunity costs of public funds are assumed fixed over time. However, in reality values in the governments' objective function are changing over time. Lobbying power of different special interest groups may not stay the same. Farmers' ability as a special interest group to provide pressure on countries' trade policy decisions has been decreasing over time, more so in the U.S. than in the EU.

The enormous budgetary costs of CAP have been a major problem for the EU. In later years, pressures on the EU budget and hence on the CAP have further increased because the EU member states are required to reduce their public expenditure in order to satisfy the Maastricht criteria for European Monetary Union. In fact, in July 1996, EU finance ministers decided on a "zero-growth" EU budget in 1997, which meant leaving EAGGF budget approximately unchanged as compared with 1996 (Tracy 1996). Although this limit

[5] In 1992/93 the wheat stock level in the EU was 24.1 million tons, but in 1995/96 the level had dropped to only 10.6 million tons (USDA).

could prove difficult to respect, it seems that the marginal costs of public funds in the EU have increased over time, but how much is difficult to say.

Similarly in the U.S., budgetary issues regarding the level and variability of Federal expenditures for farm programs were central to 1996 farm legislation discussions. Increased concern over the Federal budget deficit strengthened pressure for agricultural policy reforms (Young and Westcott 1996), indicating changes in the government's objectives. These changes in the governments' objective functions are not captured by our empirical model, and so limit the model's ability to describe long term actual behaviors when such changes are taking place in the market.

This section has described the dynamic behavior in the empirical model. A comparison of the base solution and actual values of the endogenous variables has also been made. Given the model's errors in prediction, it is useful next to explore the sensitivity of the results to changes in key parameter values. Finally, even though the ultimate judgment of the validity of the model is subjective, the author believes that the model's performance is sufficient (when its limitations are understood) to be used for export policy analysis and for studying different strategic behaviors in international wheat trade. The remainder of this chapter concentrates on doing that.

## 6.4. Analysis of Changes in the Economic Environment

Models were solved for several different time horizons, with the number of periods varying from two to 84. The results in the following tables are for a time horizon of 21 periods. For each scenario, however, only the minimum number of time periods needed to illustrate effects of economic environment changes are shown. In the first table, in which effects of switching costs are analyzed, three values for each variable in each scenario are presented. This is done to highlight switching costs' dynamic effects at the beginning and at end of the analyzed time range. The first values describe players behavior at the beginning of the dynamic game. During the intermediate time periods the model reaches a steady state. This is what the second value describes.[6] Finally, the final period values show players behaviors at the end of the dynamic game. Thereafter, only the steady-state values are generally presented for each scenario.

In addition, to better see the effects in each scenario, exporting firm's marginal costs, that are constant through time periods, are used again instead of actual marginal costs that vary between time periods. The fixed marginal costs

[6] For welfare and profits variables, steady state values are replaced by middle period values. These values describe the total discounted future welfare of an exporting country and the total discounted future profits of an exporting firm at the middle period (period 11).

are \$130 per ton for U.S. wheat exporting firm and \$190 per ton for EU wheat exporting firm. As before, initial period exports are taken from historical data.

### 6.4.1. Analysis of Changes in the Key Parameter Values

#### 6.4.1.1. Switching Costs

The first scenarios explore the consequences of switching costs. To perform this analysis, three different values of switching cost parameters are used: estimated values, no switching costs, and larger switching costs.[7] Econometrically estimated values of Chapter V were used in our base solution. A comparison between these different scenarios for the United States and for the European Union is shown in Table 6.4.

The dynamic model with switching costs converges to the steady state in the middle periods. The time that it takes for the model to converge to the steady state depends on how large switching costs are. If no switching costs are a present, then the steady state is reached immediately. With econometrically estimated parameter values of marginal switching costs it took 11 months to converge to the steady state. Under a large switching cost scenario, 20 months were required before the steady state was reached.

When switching costs are present the United States competes more aggressively in the early periods of the game than in the steady state to gain market share in the Moroccan wheat market. The aggressive behavior of the U.S. exporting firm is shown by the lower price that it charges in the early periods. The aggressive behavior of the U.S. government is shown by the larger per unit export subsidy. At the final stages of the studied time horizon the United States then exploits its current market share. The exporting firm charges a higher price than in the steady state, which implies that a smaller export subsidy by the government is needed.

Larger switching costs make these effects even stronger, as can be seen from the last column of Table 6.4. At the beginning the exporting firm competes even more fiercely in prices and the government implements larger subsidies. At the end the market share is tightly locked-in to the U.S., allowing the U.S. government to set an export tax and the exporting firm to charge a very high price.[8]

Although behaviors of the players at the beginning and at the end of the time range are important theoretical issues, the steady state is the most empirically relevant solution to study. In each steady-state time period the U.S. faces a

[7] The larger switching cost values for each wheat equal two times the econometrically estimated values.

[8] Note that in reality the final period never really occurs.

*Table 6.4. Impact of Switching Costs on the United States and the European Union.*

| | Base solution | No switching costs | Large switching costs |
|---|---|---|---|
| U.S. price ($/ton) | | | |
| first period | 156.45 | 177.86 | 86.79 |
| steady state | 165.90 | 177.86 | 150.65 |
| final period | 199.80 | 177.86 | 253.50 |
| U.S. exports (1000 tons) | | | |
| first period | 130.22 | 102.61 | 202.46 |
| steady state | 137.31 | 102.61 | 267.27 |
| final period | 118.08 | 102.61 | 155.97 |
| U.S. export subsidy ($/ton) | | | |
| first period | 39.33 | 29.44 | 72.12 |
| steady state | 34.95 | 29.44 | 44.40 |
| final period | 19.16 | 29.44 | -6.00 |
| U.S. welfare (million dollars) | | | |
| first period | 401.64 | 328.15 | 653.03 |
| middle period | 223.39 | 180.50 | 382.48 |
| final period | 22.84 | 17.25 | 39.85 |
| U.S. firm's profits (million dollars) | | | |
| first period | 184.48 | 150.91 | 312.43 |
| middle period | 102.65 | 83.01 | 183.37 |
| final period | 10.50 | 7.93 | 18.33 |
| EU price ($/ton) | | | |
| first period | 185.17 | 214.11 | 132.42 |
| steady state | 179.74 | 214.11 | 85.07 |
| final period | 213.25 | 214.11 | 192.55 |
| EU exports (1000 tons) | | | |
| first period | 84.32 | 80.32 | 70.49 |
| steady state | 81.56 | 80.32 | 39.64 |
| final period | 79.90 | 80.32 | 69.93 |
| EU export subsidy ($/ton) | | | |
| first period | 77.05 | 64.51 | 104.03 |
| steady state | 79.57 | 64.51 | 124.93 |
| final period | 64.91 | 64.51 | 74.61 |
| EU welfare (million dollars) | | | |
| first period | 241.80 | 294.48 | 54.21 |
| middle period | 133.86 | 161.98 | 32.75 |
| final period | 15.32 | 15.48 | 11.73 |
| EU firm's profits (million dollars) | | | |
| first period | 109.43 | 135.43 | 25.02 |
| middle period | 60.64 | 74.49 | 15.01 |
| final period | 7.04 | 7.12 | 5.40 |

tradeoff situation in which it can either exploit its current market share with higher price and lower export subsidy or compete for larger market share with a lower price and higher subsidy. Thus, it describes the most common real world market situation under which players are making their decisions on prices and export subsidies. The different scenarios of the dynamic model are, therefore, most conveniently compared using steady-state values.

Following Klemperer (1995), two main effects of switching costs on prices can be stated. First, to some degree an importing country has been locked-in to exporting countries. Therefore, if exporting firms cared only about their current profits, they would exploit their current market share by charging a higher price than in the absence of switching costs. On the other hand, exporting countries recognize that a lower price today increases future profits by increasing market share. Beggs and Klemperer (1992), by using a theoretical multi-period switching cost model, state that we should expect firms' incentives to exploit current market share to dominate their incentives to increase market share that would be exploited later, leading to higher prices in markets with switching costs than in markets without switching costs. They state effects that speak in favor of their claim. First, discounting ($\delta < 1$) reduces the importance of the desire to attract more market share relative to the desire to exploit current market share. Second, if one exporting firm increases its price today, its rival will gain market share today and so, may raise price tomorrow. Thus, each exporting firm has an incentive to price high today, to make its rival less aggressive tomorrow. Third, in their model buyers recognize that a lower price today is an indication of a higher price tomorrow, because a firm that sets a lower price today will obtain a larger market share and will generally set a higher price tomorrow. Therefore, buyers will be less attracted by a current low price than if there were no switching costs in the market. In international trade, if prices are expected to be higher, then we usually would expect export subsidies to be lower than in the absence of switching costs.

These claims can be tested by comparing the no switching cost scenario to the base solution. In contrast to presumption of Beggs and Klemperer, the U.S. wheat price paid by Morocco decreases from \$177.86 per ton to \$165.90 per ton when switching costs are introduced. The export subsidy set by the U.S. government rises from \$29.44 per ton to \$34.95 per ton. This higher export subsidy lowers the price of U.S. wheat, and makes U.S. wheat more attractive to Morocco. Therefore, U.S. exports increase from 102.61 thousand tons to 137.31 thousand tons.

Incentives to increase market share that would be exploited later dominate in this model. The results are not sensitive to the level of discounting. A discount rate as large as 0.65 (equals to annual interest rate of 176 percent) still results in lower steady-state prices than in the absence of switching costs.[9] In contrast to Beggs and Klemperer, this model assumes that an importing country makes its purchase decisions for the current period without regard to the future (i.e., the importing country is myopic). In addition, while Beggs and Klemperer proposition is for the case of symmetric marginal costs, we allow asymmetric marginal costs.[10]

The total discounted future welfare of the U.S. is higher when switching costs are taken into account, and the U.S. exporting firm's profits are higher, as well. This is because the estimated value of marginal switching cost parameter for U.S. wheat ($\eta^{US}$ ) is larger than the estimated value of marginal switching cost parameter for EU wheat ($\eta^{EU}$), meaning that the U.S. is able to lock in Morocco more tightly to itself than the EU is able to do. In addition, the U.S., as the low cost producer of wheat, is able to consistently hold a larger market share in Moroccan wheat imports than the EU. This further enhances the difficulty to switch away from U.S. wheat to EU wheat.

From the trade policy perspective it is clear that when analyzing a market in which switching costs are present, the ignorance of switching costs can lead to considerable errors. Per period export subsidy expenditures for the U.S. in the base solution are 4.8 million dollars. Without switching costs expenditures are only 3.02 million dollars, that is 37 percent too small. For example, the United States introduced the EEP program in 1985 to gain market share in the world wheat market. If the USDA did not take into account switching costs in its calculations, our results suggest that in the market like the Moroccan wheat market costs from the EEP bonuses for the budget of the U.S. government would be clearly underestimated.

Impacts of switching costs on the European Union are also shown in Table 6.4. Again, the presumption of Beggs and Klemperer is rejected. If the switching costs are not taken into consideration, the EU price is 19 percent higher than in the base solution and the export subsidy is 19 percent lower. Therefore, with switching costs the EU (as well as the U.S.) compete harder on the Moroccan wheat market, resulting in lower prices for Morocco. This again leads to increased export volumes by the EU.

However, the small increase in EU exports (1.5 percent) under the base solution is not able to compensate for the effects of lower price and higher subsidy. Therefore, with switching costs EU's welfare is decreased by 18 percent. Similarly, profits of the EU exporting firm are decreased by 19 percent.

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[9] In the scenario with no discounting $(\delta = 1)$ changes in the results were very small.

[10] In our model switching costs are also allowed to differ between two wheats. Asymmetry in switching costs makes it possible to examine situations in which one exporting country is able to lock in a buyer more tightly to itself than the other exporting country is able to do.

One reason for the EU side being worse off in the base solution is because of asymmetry in switching costs. Econometric estimations suggested that it is more difficult to switch away from U.S. wheat than from EU wheat.

In the scenario with large switching costs the estimated marginal switching cost parameters are doubled. Since this estimated parameter value for the U.S. was larger than for the EU to begin with, after doubling them the difference is even larger. Therefore, this scenario describes the fact that if the costs of switching to EU wheat are increased by more than costs of switching to U.S. wheat, then even though the EU is subsidizing its exports more than in the base solution and the EU exporting firm is charging lower price than in the base solution, EU is only able to export much smaller quantities to Morocco. The negative impacts on welfare and exporting firm profits are naturally larger than before.

Since the exporting country and the exporting firm clearly benefit from the increased costs of switching to rival's wheat, then an important question to ask is how switching costs arise. Because of these benefits, exporting countries certainly have incentives to exercise trade policies that would help to create switching costs. While some kinds of switching costs, e.g. transaction costs, may be unavoidable, other kinds of switching costs can be seen as the result of deliberate exporting country actions. Exporting countries' guaranteed credit programs may be seen as one way to create switching costs. If switching costs created by, for example, a GMS-103 loan increase future welfare to the U.S. more than any current costs to the U.S. of creating them, then such a loan should be guaranteed to Morocco.

Finally, market shares are commonly used measures of export performance (Gehlhar and Vollrath 1997). Our model of Moroccan wheat import market where switching costs seem to exist can provide some insight for this importance attached to market shares by exporting countries. If an exporting country is able to increase its market share, this creates additional costs for the importing country (Morocco) to switch away from that exporting country's wheat in the future. Each exporting country and each exporting firm realize this. Therefore, their behaviors are not just driven by maximization of current period welfare (exporting country) and profits (exporting firm), but also by the interest to increase current market share which would improve future welfare of that exporting country and future profits of the exporting firm. Hence, the notion of switching costs in the market provides an intuitive explanation why exporting countries and firms are often concerned with market share in addition to short run welfare and profits, respectively.

### 6.4.1.2. Opportunity Costs of Public Funds

Taxes introduce distortions in the allocation of resources. Increasing attention has been given to the significance of the welfare cost of taxation in the analysis of public expenditure programs. If the financing of expenditure programs involves a welfare cost, then this cost should be considered part of the opportunity cost of expenditure programs. Put briefly, when the EU spends $100 on export refunds, the opportunity cost is $100 plus the additional welfare loss involved in acquiring the funds. Thus, the export refunds are efficient only if their benefits exceed the direct tax costs by an amount at least as large as the additional welfare cost of the funds.

In the literature on public finance estimates for the additional welfare cost of public funds range from 17 percent to 56 percent of additional tax revenue raised. In the base solution the value that we used for opportunity (or marginal) cost of public funds is 1.332 (i.e., the additional welfare cost is 33.2 percent), and it is the same for both exporting countries.

In our analysis we now compare the base solution to two other scenarios. One alternative scenario ignores the additional welfare cost of public funds and the other one assumes that they are very large, that is 56 percent (i.e., the upper bound in empirical estimations for the U.S. economy).

The simulation results for two alternative scenarios are compared to base values in Table 6.5. If opportunity cost of a dollar of government spending is only one dollar, then the per unit export subsidy paid by the U.S. government is almost three-times as large as in the base solution. Because of the large export subsidy the U.S. exporting firm ends up exporting 21 percent more wheat with a price that is 36 percent lower than in the base solution. The exporting firm's total discounted future profits are greatly improved. The lower selling price is more than offset by the increased exports and a larger export subsidy.

The U.S. government (as well as the EU government) is more willing to use large export subsidies as a policy tool when no marginal excess burden of public funds exists. Therefore, the two superpowers engage themselves in an even more severe subsidy war when fighting over market shares. This much larger use of subsidies decreases the total discounted future welfare of each exporting country, regardless of which value of opportunity cost of public funds is used to compare welfares.

The EU government awards export refunds that are over 50 percent higher than the price paid by Morocco on that subsidized wheat. The heavy subsidy allows the EU exporting firm to charge a lower price than its U.S. counterpart, but this surprisingly increases EU exports less than U.S. exports (only by 17 percent). The reasons are that switching costs favor the U.S. more than the EU and that the own-price elasticity for U.S. wheat is larger than the own-price elasticity for EU wheat. However, the total discounted future profits of the EU

*Table 6.5. Impacts of Changes in Opportunity Costs of Public Funds on the European Union and the United States.*

| | Base Solution | No additional welfare cost of public funds | High additional welfare cost of public funds |
|---|---|---|---|
| U.S. price ($/ton) | | | |
| steady state | 165.90 | 106.59 | 188.82 |
| U.S. exports (1000 tons) | | | |
| steady state | 137.31 | 165.58 | 126.83 |
| U.S. export subsidy ($/ton) | | | |
| steady state | 34.95 | 99.80 | 8.89 |
| U.S. welfare (million dollars) | | | |
| total discounted future welfare | 401.64 | 334.76 | 442.07 |
| U.S. firm's profits (million dollars) | | | |
| total discounted future welfare | 184.48 | 240.04 | 162.84 |
| EU price ($/ton) | | | |
| steady state | 179.74 | 105.41 | 208.64 |
| EU exports (1000 tons) | | | |
| steady state | 81.56 | 95.72 | 75.70 |
| EU export subsidy ($/ton) | | | |
| steady state | 79.57 | 158.94 | 47.43 |
| EU welfare (million dollars) | | | |
| total discounted future profits | 241.80 | 196.96 | 265.99 |
| EU firm's profits (million dollars) | | | |
| total discounted future profits | 109.43 | 139.17 | 96.59 |

exporting firm are still increased through larger export refunds. In the case of high marginal cost of public funds both exporting countries award export subsidies more conservatively than in the base solution. This implies that higher prices are charged by exporting firms and export volumes are smaller. Since attractiveness of export subsidies as a policy tool is diminished, exporting countries do not get involved in as tough a subsidy war game. Therefore, total discounted welfares of these countries increase. However, exporting firms are worse off, since effects of reduced exports and export subsidies on firms' profits are greater than effects of increased prices.

### 6.4.1.3. Marginal Costs

Two basic elements that establish the wheat exporting firms' marginal costs are domestic producer price of wheat and transportation costs. The MacSharry CAP reform reduced internal support prices in the EU by 30 percent. This section analyzes the impacts of this EU internal price reduction on wheat trade to Morocco by lowering the marginal cost of the EU exporting firm by 30 percent.

Another issue analyzed here is a zero marginal cost assumption. To (1994), who was the first to introduce switching costs into the international trade framework, in his theoretical two-period model assumed that marginal costs for each exporting firm are zero. By comparing the scenario with zero marginal costs to the base solution, we show how this empirically unrealistic assumption changes the results in our model.

Table 6.6 shows the adjustments in wheat trade to Morocco following the reduction in EU support prices. As a result of this reduction, a major decrease occurs in the level of export subsidy that the EU government sets. To cut back in export subsidy expenditures the EU awards a per unit subsidy which is 59 percent smaller than the subsidy awarded before the reform.

It is usually expected that if domestic prices are decreased, then export subsidies would be lower and export prices higher than before. However, this is

*Table 6.6. Impacts of Changes in Marginal Costs of Exporting Firms on the European Union and the United States.*

| | Base Solution | CAP reform; marginal cost of EU firm reduced by 30 % | Zero marginal costs |
|---|---|---|---|
| EU price ($/ton) | | | |
| steady state | 179.74 | 173.68 | 147.29 |
| EU exports (1000 tons) | | | |
| steady state | 81.56 | 86.58 | 90.74 |
| EU export subsidy ($/ton) | | | |
| steady state | 79.57 | 32.9 | -70.17 |
| EU welfare (million dollars) | | | |
| total discounted future welfare | 241.80 | 271.90 | 298.89 |
| EU firm's profits (million dollars) | | | |
| total discounted future welfare | 109.43 | 123.05 | 135.27 |
| U.S. price ($/ton) | | | |
| steady state | 165.90 | 162.69 | 141.26 |
| U.S. exports (1000 tons) | | | |
| steady state | 137.31 | 134.00 | 145.29 |
| U.S. export subsidy ($/ton) | | | |
| steady state | 34.95 | 36.46 | -66.29 |
| U.S. welfare (million dollars) | | | |
| total discounted future profits | 401.64 | 382.86 | 449.65 |
| U.S. firm's profits (million dollars) | | | |
| total discounted future profits | 184.48 | 175.86 | 206.54 |

only partially true here. Although the EU government greatly decreases its subsidy level, it still provides a subsidy that keeps EU wheat competitive against U.S. wheat in the Moroccan market. In fact, the combination of export subsidy (even though lower than before) and lower marginal cost makes it possible for the EU exporting firm to charge a three percent lower price than before the reform. The lower price then allows the EU to capture some of the market share from the U.S. Therefore, the European Union as well as its exporting firm benefit more from wheat trade to Morocco after the reform than before it. Total discounted welfare of the EU and total discounted profits of the EU firm from wheat exports to Morocco are both increased by 12 percent in this scenario.

The impacts of the reduction in EU support prices on the United States might be surprising to some readers. The U.S. exporting firm is now actually facing more severe price competition from its EU rival in the Moroccan wheat market. The U.S. firm is, therefore, forced to lower its export price. This lower price means that the U.S. government has to provide larger EEP-bonuses for the exporting firm to keep U.S. wheat competitive in the import market. However, the reduction in the U.S. wheat price is still less than in the EU wheat price. Therefore, the U.S. loses only a small portion of its market share.[11] Since the price and exports of U.S. wheat are decreased and export subsidy expenditures are increased, it is clear that reduction in support prices of the EU makes the U.S. benefit less from its wheat trade to Morocco. Also, the total discounted profits of the U.S. exporting firm are lower.[12]

The last column of Table 6.6 shows the simulation results with zero marginal costs for both the EU and U.S. The important thing to notice is that export policies have changed. Instead of subsidizing wheat exports, governments are now taxing their exports. Therefore, levels of marginal costs are playing a significant role in export policy choice.

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[11] The results appear to be consistent with actual data. Actual data showed that the average monthly subsidy for EU wheat was reduced from $108 per ton in 1992/93 to $77 per ton in 1993/94, while the average monthly subsidy for U.S. wheat exports to Morocco was increased from $31 per ton in 1992/93 to $37 per ton in 1993/94. Observed prices paid by Morocco for EU wheat and U.S. wheat were reduced: average monthly price for EU wheat from $146 per ton in 1992/93 to 114 per ton in 1993/94 and average monthly price for U.S. wheat from $126 per ton in 1992/93 to 102 per ton in 1993/94. Furthermore, EU wheat exports to Morocco increased from 79 thousand tons in 1992/93 to 95 thousand tons in 1993/94, while U.S. wheat exports to Morocco decreased from 141 thousand tons in 1992/93 to 101 thousand tons in 1993/94.

[12] Recall that our analysis does not capture the effects that CAP reform has on domestic wheat production and consumption in the EU. If the need for exports are greatly reduced through the reform's effects on EU's production and consumption, then exporting countries behaviors in international wheat market might be different.

In his model, To (1994) used a standard Brander-Spencer framework in which an objective function for the exporting country's government is profits of that country's exporting firm less export subsidy expenditures.[13] With that model he was able to state that exporting firms always set export taxes in the second period and this result was independent of marginal costs. If we apply the standard Brander-Spencer form of government objective function to our empirical dynamic model we get results that are consistent with To's results. In every steady-state period each exporting country is using an export tax as the optimal trade policy, and this outcome is independent of marginal cost levels.[14] It seems that our model, in which export subsidies can be realized as a trade policy option, is better suited to describing real world phenomena of international wheat trade.

#### 6.4.1.4. Product Differentiation

Estimations in Chapter V showed that EU wheat and U.S. wheat are imperfect substitutes in the Moroccan wheat market. This section illustrates the effects of changes in the level of product differentiation on the behaviors of the U.S. and the EU in wheat trade to Morocco. In the base solution the product differentiation index equals approximately 0.55. For comparison two alternative scenarios show the results when product differentiation is either lower or higher than in the base solution. In the highly differentiated product case the index value is 0.4, and in the low product differentiation case, in which EU wheat and U.S. wheat are closer substitutes, the index value equals 0.65.[15]

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[13] Recall that in our model the objective function of a government is export revenue less export subsidy expenditures, where the additional welfare cost of public funds is taken into account.

[14] When our model is solved with Brander-Spencer objective functions, export taxes set by the U.S. and the EU are \$24.12 per ton and \$17.42 per ton, respectively. With zero marginal costs export taxes set by the U.S. and the EU are \$30.20 per ton and \$31.06 per ton, respectively, and if we double the base values of marginal costs then the U.S. sets an \$18.04 export tax and the EU sets a \$3.77 export tax. If marginal costs become so high that negative exports from the EU and/or the U.S. are optimal, then a subsidy would become optimal. But in this case the EU and/or the U.S. would not be an exporter anymore. It would be importing wheat from Morocco and the subsidy would be an import subsidy.

[15] To measure the degree of product differentiation, recall from Chapter V that the demand structure used in the empirical model is

(6.1) $$M_t^i = z^i - b^i\left(P_t^i - \eta^i M_{t-1}^i\right) + e\left(P_t^k - \eta^k M_{t-1}^k\right),$$

where $i \neq k$ and $i =$ U.S., EU. In order to get inverse demand functions, we invert the system given in (6.1). The inverse demand functions are

(6.2) $$P_t^i - \eta^i M_{t-1}^i = \alpha^i - \beta^i M_t^i - \gamma M_t^k,$$

where $\alpha^i = \left(z^i b^k + z^k e\right)/\left(b^i b^k - e^2\right)$, $\beta^i = b^k/\left(b^i b^k - e^2\right)$, and $\gamma = e/\left(b^i b^k - e^2\right)$ for $i \neq k$

The simulation results of these three scenarios are presented in Table 6.7. It is clear that an increase in product differentiation gives more market power to the exporting side by loosening up price competition among exporting firms and export subsidy competition between governments. In the case of high product differentiation both exporting firms are charging higher prices and both exporting country governments are providing lower export subsidies than in the base solution. The low substitutability between wheats implies also that considerable increases in price do not lower export volumes much. For example, the price of exported EU wheat increases 26 percent, and export volume is basically unchanged (decreases by 0.13 percent).

*Table 6.7. Impacts of Changes in the Level of Product Differentiation on the European Union and the United States.*

| | Base Solution | Low product differentiation | High product differentiation |
|---|---|---|---|
| U.S. price ($/ton) | | | |
| steady state | 165.90 | 140.22 | 200.32 |
| U.S. exports (1000 tons) | | | |
| steady state | 137.31 | 151.03 | 125.63 |
| U.S. export subsidy ($/ton) | | | |
| steady state | 34.95 | 44.44 | 25.52 |
| U.S. welfare (million dollars) | | | |
| total discounted future welfare | 401.64 | 358.95 | 456.98 |
| U.S. firm's profits (million dollars) | | | |
| total discounted future profits | 184.48 | 156.40 | 228.33 |
| EU price ($/ton) | | | |
| steady state | 179.74 | 143.72 | 226.51 |
| EU exports (1000 tons) | | | |
| steady state | 81.56 | 79.77 | 81.45 |
| EU export subsidy ($/ton) | | | |
| steady state | 79.57 | 94.32 | 64.78 |
| EU welfare (million dollars) | | | |
| total discounted future profits | 241.80 | 176.08 | 320.13 |
| EU firm's profits (million dollars) | | | |
| total discounted future profits | 109.43 | 75.35 | 158.29 |

and $i$ = U.S., EU. Varian (1992) states that in general, $\gamma^2/(\beta^i\beta^k)$ can be used as an index of product differentiation. When this term is one, the goods are perfect substitutes, and when it is zero, markets of these two goods are independent. Thus, values that the index can have range from zero to one.

Higher prices paid by Morocco and lower export subsidy levels together with moderately lower exports make exporting countries better off. Total discounted profits of exporting firms are also increased. Thus, the results are consistent with static theoretical Bertrand (as well as Cournot) games with product differentiation, which say that the profits of firms increase when products become more differentiated (Shy 1995). It is also interesting to notice that the EU side benefits more from increased product differentiation. The total discounted future welfare of EU increases by 32 percent, while the corresponding change in the U.S. is 14 percent. Similarly, the EU exporting firm receives a larger increase in its total profits. One of the reasons for this outcome is found from the more inelastic import demands for both wheats in the highly differentiated products case than in the base solution. The reduction in the own-price elasticity of EU wheat is larger (6.2 percent) than the reduction in the own-price elasticity of U.S. wheat (1.9 percent). So, when the level of competition against the U.S. wheat is lowered through product differentiation, the EU exporting firm increases its price more relative to the U.S. firm. The higher price level then allows the EU government to decrease its very large export subsidy expenditures more than the U.S. counterpart. Thus, the EU side benefits from higher product differentiation more than the U.S. side.

When EU wheat and U.S. wheat become increasingly substitutable, it follows that there is increased price competitiveness through increased subsidies. The prices are lower and draw closer together. Total imports of wheat to Morocco are increased, but imports of EU wheat are actually reduced. The U.S., as a low cost producer, is able to capture larger market share at an expense of the EU when competition is more fierce.

### 6.4.1.5. Asymmetries in Parameters

The empirical model of the Moroccan wheat market is asymmetric and that asymmetry affects players' equilibrium strategies in the market. This section examines the effects of asymmetries on model outcomes. The three asymmetries to be studied are the asymmetry in exporting firms' marginal costs ($C_t^{US} \neq C_t^{EU}$), the asymmetry in marginal switching costs ($\eta^{US} \neq \eta^{EU}$), and the asymmetry in own-price effects on wheat imports ($b^{US} \neq b^{EU}$).[16]

First, in order to study effects of asymmetries we need to create a fully symmetric model as a basis for comparison. The new parameter values of import demand functions and of marginal costs used to construct the fully symmetric model are shown in Table 6.8. These symmetric parameter values are derived from the estimated parameter values by taking the mean of estimated

[16] Own-price effects are the parameter values in our estimated, linear import demand functions ($b^i$) and while closely related to, should not be confused with own-price elasticities.

*Table 6.8. Parameter Values of Import Demand Functions and of Marginal Costs Used in the Symmetric and Asymmetric Models.*

| | Own-price effect | Cross-price effect | Marginal switching cost | Exporting firms' marginal costs |
|---|---|---|---|---|
| Symmetric | $b = 1.117$ | $e = 0.816$ | $\eta = 0.309$ | $C_t = 160$ |
| U.S. | $b^{US} = 1.327$ | $e = 0.816$ | $\eta^{US} = 0.354$ | $C_t^{US} = 130$ |
| EU | $b^{EU} = 0.906$ | $e = 0.816$ | $\eta^{EU} = 0.264$ | $C_t^{EU} = 190$ |

U.S. and EU values. The last two rows of the same table presents parameter values used in asymmetric scenarios (and subsequent scenarios of this thesis).

The results of the fully symmetric model are derived and compared with three other scenarios, each of which illustrates a situation in which one of the three asymmetries is introduced into the otherwise symmetric model. Results of these four model outcomes are shown in Table 6.9.

The first asymmetry analyzed is that between marginal costs of two exporting firms. The U.S. exporting firm is the low-cost exporter ($130 per ton) compared to the EU firm ($190 per ton). Differences between results of a fully symmetric model and results of an otherwise identical model, except that marginal costs for U.S. firm are lower than for the EU firm, are discussed in order to see the effects of marginal cost asymmetry.

Relatively lower marginal cost makes U.S. wheat more competitive in the importing country. The U.S. exporting firm charges a lower price and also a smaller export subsidy is needed from the U.S. government to export U.S. wheat than in the symmetric case. The change in the wheat price, however, is very small relative to the change in the U.S. marginal cost. Since U.S. government (as a leader) has more market power than the U.S. firm (as a follower), most of the effects of lower U.S. marginal cost can be seen as a reduction of export subsidies. The somewhat lower price enables the U.S. to capture a larger share of the importing country's wheat market. Both the U.S. exporting firm and U.S. government are better off in the asymmetric case, with higher profits and welfare than in the symmetric case. The effects of marginal cost asymmetry on the EU side are opposite to U.S. effects, since EU marginal costs are higher, making EU government and the EU firm worse off when compared with the fully symmetric case.

The second asymmetry in our empirical model is between costs of switching. It is more difficult for the Morocco to switch away from U.S. wheat than from EU wheat. That is, the estimated marginal switching cost parameter for U.S. wheat is larger than for EU wheat ($\eta^{US} = 0.354$; $\eta^{EU} = 0.264$). Comparison between a fully symmetric model and an otherwise identical model, except that

*Table 6.9. Impacts of Asymmetries on Model Outcomes.*

| | Symmetric case | Marginal cost asymmetry $C_t^{US} = 130$ $C_t^{EU} = 190$ | Marginal switching cost asymmetry $\eta^{US} = 0.354$ $\eta^{EU} = 0.264$ | Own-price effect asymmetry $b^{US} = 1.327$ $b^{EU} = 0.906$ |
|---|---|---|---|---|
| U.S. price ($/ton) | | | | |
| steady state | 170.05 | 168.97 | 169.44 | 168.65 |
| U.S. exports (1000 tons) | | | | |
| steady state | 105.20 | 110.37 | 107.90 | 127.04 |
| U.S. export subsidy ($/ton) | | | | |
| steady state | 59.23 | 33.72 | 59.73 | 59.48 |
| U.S. welfare ($million) | | | | |
| total discounted future welfare | 167.55 | 184.18 | 170.70 | 199.74 |
| U.S. firm's profits (million) | | | | |
| total discounted future profits | 77.29 | 84.96 | 78.99 | 91.47 |
| EU price ($/ton) | | | | |
| steady state | 170.05 | 171.12 | 170.53 | 177.73 |
| EU exports (1000 tons) | | | | |
| steady state | 105.20 | 100.02 | 102.61 | 86.30 |
| EU export subsidy ($/ton) | | | | |
| steady state | 59.23 | 84.75 | 58.80 | 54.65 |
| EU welfare (million) | | | | |
| total discounted future welfare | 167.55 | 151.70 | 164.42 | 146.64 |
| EU firm's profits (million) | | | | |
| total discounted future profits | 77.29 | 69.98 | 75.61 | 66.62 |

the marginal switching cost for U.S. wheat is larger than for EU wheat, shows that higher costs of switching away from U.S. wheat make the U.S. compete more aggressively in the importing market. This means that the U.S. exporting firm charges a lower price and the U.S. government awards a higher export subsidy than in the fully symmetric model. The lower price makes U.S. wheat more attractive to Morocco, leading to increased U.S. wheat exports to Morocco. These increased exports more than compensate for the effects of lower price and higher subsidy, making the U.S. government benefit more from wheat trade to Morocco. Similarly, profits of the U.S. exporting firm are increased from the symmetric model level.

The asymmetry in marginal switching costs makes it easier to switch away from EU wheat. Therefore, the EU is less willing to compete over market shares than in the symmetric case. It behaves less aggressively, with higher prices and lower subsidies than before, resulting in decreased export volumes of EU wheat. Both EU government and the exporting firm are worse off in this asymmetric case.

The third asymmetry is between own-price effects on wheat imports. Imports of U.S. wheat appear to be more sensitive to own-price changes than imports of EU wheat ($b^{US} = 1.327$; $b^{EU} = 0.906$). We compare a fully symmetric model and an otherwise identical model, except that the own-price effect for U.S. wheat is larger than for EU wheat.

Since in the asymmetric case a decrease in U.S. wheat price results in a larger increase in U.S. wheat exports than in the fully symmetric case, the U.S. competes more aggressively in the importing market. A lower price is set by the U.S. exporting firm and a higher subsidy is awarded by the U.S. government, leading to increased exports of U.S. wheat to the importing country. Again, both U.S. government and the exporting firm are better off, as can be seen from Table 6.9. On the other hand, a decrease in the EU wheat price, due to asymmetry, would now have a smaller impact on EU wheat exports than in the fully symmetric case. Therefore, the EU firm and the EU government adopt less aggressive pricing and export subsidy strategies than in the symmetric case. That is, the EU exporting firm sets its price higher than before, and smaller export subsidies are awarded by the EU government to sell wheat to the importing country. However, decreased export volumes in the asymmetric case makes the EU government and the EU exporting firm benefit less from their wheat trade to Morocco.

All three asymmetries in our empirical model affect in the same way prices, exports, exporting firms' profits, and governments' welfares. They lower EU exports, U.S. price, the EU exporting firm's profits and EU government's welfare. They increase U.S. exports, EU price, the U.S. exporting firm's profits as well as the U.S. government's welfare.

Effects of asymmetries on export subsidies are more complex. Asymmetries in own-price effects and marginal switching costs decrease the EU export subsidy and increase the U.S. subsidy, but the asymmetry in marginal costs of exporting firms has an opposite impact on export subsidies.

As a final task of this section we illustrate the relative importance of each asymmetry. This is done by using an elasticity type, unit free measure to describe effects of each asymmetry on prices, export volumes, export subsidies, welfares, and profits. This measure is the difference in relative changes in a variable of interest (e.g., price) divided by the difference in relative changes in a parameter value of interest (e.g., own-price effect).[17] The results are presented in Table 6.10.

[17] Using steady-state values of the symmetric and asymmetric models, the unit free measure describing, for example, the impact of asymmetry in own-price effects on price difference is given by $\left[(P_A^{US} - P_S)/P_S - (P_A^{EU} - P_S)/P_S\right]/\left[2(\Delta b)/b\right]$, where $P_A^i$ is the steady-state price of exporting country $i$'s wheat in the asymmetric model $P_S$, is the steady state price of the symmetric model, and $\Delta b = (b^{US} - b^{EU})/2$ is the deviation from the symmetric parameter value of own-price effect, $b$.

*Table 6.10. Impacts* of Asymmetries on Price, Exports, Export Subsidy, Welfare, and Profits.*

| | Asymmetry in marginal cost | Asymmetry in marginal switching costs | Asymmetry in own-price effects |
|---|---|---|---|
| Impact on price difference | -0.0337 | -0.0220 | -0.1416 |
| Impact on exports difference | 0.2622 | 0.1728 | 1.0273 |
| Impact on export subsidy difference | -2.2975 | 0.0539 | 0.2163 |
| Impact on welfare difference | 0.5168 | 0.1288 | 0.8407 |
| Impact on profits difference | 0.5168 | 0.1501 | 0.8528 |

*Impact indicates the difference in percentage changes in a variable of interest divided by difference in percentage changes in a parameter value of interest for U.S. variable less EU variable.

The asymmetry between own-price effects appears to have the most significant impact on wheat export volumes, prices, welfares, and profits. This is saying that with a similarly sized percentage deviation in marginal costs, in marginal switching costs or in own-price effects from the fully symmetric case, it is changes in own-price effects that are causing the largest changes in export volumes, prices, welfares, and profits. Export subsidies, however, are influenced most by asymmetry between exporting firms' marginal costs, if a similarly sized percentage deviation in marginal costs, in marginal switching costs or in own-price effects from the fully symmetric case occurs. Furthermore, the impact of this marginal cost asymmetry on export subsidies is in the opposite direction of the impacts of the other two asymmetries on export subsidies. This means that in a model in which all three asymmetries are present, the impacts of the asymmetry between marginal costs are diminished by the counter effects of the two other asymmetries.

In order to see if effects of the marginal cost asymmetry on export subsidies dominates effects of the other two asymmetries in our empirical model that includes all three asymmetries, the numbers in the third row of Table 6.10 need to be properly adjusted. This is because the percentage deviations from the symmetric parameter values are not the same for every asymmetry in the empirical model. In fact, in case of marginal costs, the percentage change in marginal costs parameter values is 0.375 ($=2(\Delta C_t)/C_t$), in the case of marginal switching cost asymmetry the corresponding percentage change is 0.291 ($\doteq 2(\Delta\eta)/\eta$), and for the asymmetry in own-price effects this percentage change is 0.377 ($=2(\Delta b)/b$). So, in order to compare impacts of the three asymmetries on export subsidies in our empirical model we need to multiply the numbers in Table 6.10 by corresponding weights given above. This procedure yields the following impacts on export subsidies for each asymmetry: for asymmetry in marginal costs it is -0.862; for asymmetry in marginal switching costs it is 0.016; and for asymmetry in own-price effects it is 0.082. Thus, impact of the marginal cost asymmetry clearly dominates impacts of the other two asymmetries on export subsidies in the empirical model, implying lower export subsidies for U.S. wheat and higher export subsidies for EU wheat than in the case of symmetric model.

Finally, in this chapter several different scenarios are explored using our asymmetric empirical model. When these scenarios are examined, it is important to keep in mind the effects of model asymmetries. This section has shown that the model's asymmetries benefit the U.S., but not the EU. They make the U.S. price more aggressively than the EU, leading to larger U.S. market share in the Moroccan wheat market. In addition, the U.S., due to asymmetries, can capture this larger market share while subsidizing its wheat exports less than the EU. So, in general asymmetries allow the U.S. government and the U.S. exporting firm to benefit more from wheat trade with Morocco than their EU counterparts do.

### 6.4.2. Trade Policy Analysis

Export subsidies were not eliminated by Uruguay Round GATT agreement. Rather, no new subsidies may be introduced, and EU and U.S. export subsidies are subject to both financial and quantitative constraints. Initially, the United States proposed total elimination of all agricultural subsidies, and especially explicit export subsidies, so many took the outcome of the GATT as disappointing. From the game theory perspective, GATT could have taken the players out of their prisoner's dilemma and permitted improved welfare of the world. But the major players – the U.S. and the EU – have market power in trade, and this together with their domestic income redistribution goals mean that trade intervention may indeed be rational when players are looking only at their self-interest. The situation prior to the Uruguay Round agreement reflected this situation. The existence of a trade intervention reflected market power in trade, and export subsidies rather than export taxes reflected the producer bias of trade policy.

#### 6.4.2.1. Effects of Alternative Institutional Arrangements

In this section alternative institutional arrangements, and hence potential GATT outcomes, are analyzed. The presumption here is that World Trade Organization (WTO) sets the rules for trade, and hence the institutional arrangement. Under each structure the EU and the U.S. and their wheat exporting firms will set their strategies in their self-interest. The base solution corresponds to the pre-GATT situation. Unilateral reform scenarios refer to cases in which only the reformer eliminates its export subsidy program. In the GATT outcome scenario the export subsidy of EU wheat is limited to 51 percent of the pre-GATT level found in the base solution, and the export subsidy of U.S. wheat is limited to 43 percent of the pre-GATT solution.[18] A cartel scenario illustrates the collusive behavior of exporting countries. The EU government and the U.S. government set their export subsidies (taxes if negative) to maximize their joint welfare. Finally, the sixth scenario presents a free trade outcome. Simulation results are shown in Table 6.11.

#### 6.4.2.1.1. Unilateral Reform

If the EU unilaterally eliminates its export subsidies, then the price of exported EU wheat is increased by 24 percent. This higher EU wheat price makes it possible for the U.S. to increase its wheat price, as well. However, only a 13 percent increase occurs in the price of U.S. wheat. The reason is that the U.S. continues an aggressive export subsidy policy in order to win as much market share as possible from the EU. In fact, the U.S. actually subsidizes its wheat exports to Morocco slightly more than in the base solution. Consequently, U.S. wheat exports are increased by 23 percent and the EU is able to export only half as much as before. The welfare of the U.S. is clearly improved, but the largest benefits are obtained by the U.S. exporting firm, whose total discounted profits are increased by nearly 60 percent. On the other hand, the EU welfare is reduced by 27 percent, and the wheat exporting firm of the EU faces a substantial (75 percent) reduction in its level of profits.

When the U.S. unilaterally eliminates its export subsidies then the qualitative results of the previous paragraph are reversed. However, since the U.S. is the low cost producer of wheat and costs of switching away from U.S. wheat are higher, negative effects of subsidy elimination on the U.S. welfare and the U.S. firm's profits are considerably smaller than the effects on the EU in the previous scenario.

#### 6.4.2.1.2. GATT Outcome

The actual GATT outcome, a 49 percent reduction in the EU export subsidy and 57 percent reduction in the U.S. export subsidy, results in small increases (relative to the export subsidy reductions) in wheat prices. The $19.92 per ton

[18] In general, reductions in export subsidies are mentioned to be 36 percent for both EU and U.S. wheat. However, when the front-loading provision is taken into account, the reduction for EU wheat is 49 percent and for U.S. wheat it is 57 percent of the 1991/92 base case level (see footnote 11 in Chapter II).

*Table 6.11. Impacts of Different Institutional Arrangements on the European Union and the United States.*

| | Base Solution | Unilateral reform by EU | Unilateral reform by U.S. | GATT outcome | Covernment cartel | Free trade |
|---|---|---|---|---|---|---|
| U.S. price ($/ton) | | | | | | |
| steady state | 165.90 | 186.92 | 180.95 | 174.01 | 269.15 | 191.71 |
| U.S. exports (1000 tons) | | | | | | |
| steady state | 137.31 | 168.92 | 105.30 | 147.63 | 109.97 | 154.31 |
| U.S. export subsidy ($/ton) | | | | | | |
| steady state | 34.95 | 36.44 | 0 | 15.03 | -93.06 | 0 |
| U.S. welfare ($million) | | | | | | |
| total discounted future welfare | 401.64 | 554.74 | 363.39 | 470.99 | 618.25 | 555.51 |
| U.S. firm's profits (million) | | | | | | |
| total discounted future profits | 184.48 | 295.66 | 103.70 | 166.51 | 96.00 | 180.40 |
| EU price ($/ton) | | | | | | |
| steady state | 179.74 | 223.47 | 188.21 | 195.83 | 318.26 | 224.32 |
| EU exports (1000 tons) | | | | | | |
| steady state | 81.56 | 40.01 | 99.77 | 67.18 | 37.72 | 49.69 |
| EU export subsidy ($/ton) | | | | | | |
| steady state | 79.57 | 0 | 91.44 | 40.58 | -102.31 | 0 |
| EU welfare (million) | | | | | | |
| total discounted future welfare | 241.80 | 176.61 | 301.49 | 237.89 | 261.00 | 219.07 |
| EU firm's profits (million) | | | | | | |
| total discounted future profits | 109.43 | 27.69 | 170.01 | 62.05 | 20.70 | 35.30 |

reduction in the U.S. export subsidy implies only $8.11 per ton higher price for U.S. wheat. Although the EU subsidy is decreased as much as $38.99 per ton, the increase in the EU wheat price is only $16.09 per ton. The EU exports less wheat to Morocco, but exports of U.S. wheat are larger than in the base solution.

One reason for this outcome arises from switching costs. First, when switching costs exist in the market, the EU and the U.S. are playing more aggressive strategies (charging lower prices) in order to capture market share than if switching costs were not present. To show that this is the case we analyzed the GATT outcome in the model without switching costs. Results show that price increases would have been larger, with the U.S. wheat price increasing by $12.63 per ton and EU wheat price increasing by $17.66 per ton. Second, in our empirical model, costs of switching away from U.S. wheat are greater than costs of switching away from EU wheat. Therefore, the U.S. price is not increased as much as the EU price, because the U.S. is relatively more interested in gaining market share than the EU. Thus, the U.S. ends up exporting more than in the pre-GATT situation. The model in which switching costs are not taken into account shows both exporting countries are exporting smaller amounts than in the pre-GATT situation.

Another factor leading to a smaller increase in the U.S. price than in the EU price is the way the export subsidy constraints of GATT are introduced. For EU wheat, the export subsidy is set to be 49 percent lower than in the base solution, and for U.S. wheat, the export subsidy is set to be 57 percent lower than in the base solution. However, the base solution values of export subsidies differ in absolute values (the base subsidy for EU wheat is $79.57, while the base subsidy for U.S. wheat is $34.95). This means that in the GATT outcome scenario the firm exporting EU wheat receives $38.99 smaller subsidy for each exported ton of wheat than in the base solution. For the firm exporting U.S. wheat, however, the reduction in subsidy is only $19.92 per ton. Therefore, the pressure created by GATT-constraints to increase price in EU wheat is larger than in U.S. wheat.

#### 6.4.2.1.3. Cartel of Exporting Countries

The government cartel scenario assumes the policymakers for the European Union and the United States agree to adopt export policies consistent with joint welfare maximization. This type of institutional arrangement allows the exporting countries' governments to capture almost all of the market power. In cooperation they are able to set very high export taxes to extract rents from exporting firms. This leads to much higher prices paid by Morocco on both wheats and so, greatly decreased total wheat imports by Morocco.

The exporting firms, together with the importing country, are the big losers in this scenario. Prices are higher, but more than 30 percent of those prices go to governments through export taxes. So, the actual price (price – export tax) received by the U.S. exporting firm for its wheat is 12 percent lower than in the base solution. Similarly, the exporting firm of the EU faces a price that is now 17 percent below the base solution price. When these lower prices are combined with much reduced export volumes, it is clear that exporting firms are worse off. Total discounted future profits of the U.S. firm are just 52 percent of the base solution profits. On the EU side, the government captures most of the rents since the EU exporting firm's profits are decreased by 81 percent.

Welfares of both exporting countries are increased under the cartel arrangement. Again, the effects of different levels of switching costs cause the U.S. to benefit more than the EU. The U.S. welfare is increased by 54 percent, but EU welfare is increased by just 8 percent. Since joint welfare is 37 percent higher than in the base solution, some possible side payments within the cartel would need to take place. Although, the cartel greatly improves the welfares of the exporting countries, its appearance is not very likely. Joint setting of subsidies by the EU and the U.S. and possible explicit side payments are probably GATT-illegal, or at least politically incorrect.

#### 6.4.2.1.4. Free Trade

The final scenario illustrates the case when no government intervention is present. These free trade results are intuitively clear. Prices paid by Morocco on EU wheat and U.S. wheat are higher than in the base solution, because effects of export subsidies have disappeared. Due to higher marginal costs the EU has subsidized its wheat exports more than the U.S. did in the base solution. Therefore, the elimination of these subsidies in free trade implies a larger increase in the price of EU wheat (25 percent) than in the price of U.S. wheat (16 percent). This change in relative prices means that the U.S. exporting firm is able to increase wheat exports by 12 percent, but wheat exports by the EU exporting firm are reduced by 39 percent.

The welfare of the U.S. is substantially increased from the base solution, since larger amounts of wheat exports are incorporated with higher prices and with zero export subsidy expenditures. However, for the EU the considerable drop in export volumes outweighs positive effects of higher price and of savings in subsidy expenditure, resulting in a lower level of EU welfare. At the exporting firm level, the elimination of subsidies means that total prices received by the firms are decreased. Profits of the EU exporting firm drop by as much as 68 percent. For the U.S. wheat exporting firm, however, profits are only two percent lower, due to increased export volumes to Morocco.

#### 6.4.2.1.5. The Link Between CAP Reform and the GATT Agreement

As a final task in this section welfare effects of alternative institutional arrangements are compared. For the reader's convenience, the welfare results are presented in Table 6.12. Unilateral reform scenarios describe well the problematic situation that exists in the international wheat market, since unilateral reform is always the worst case for the country that reforms.

In this problematic situation such a reform is the best outcome for the country that retains its subsidies. If we consider cartel between governments as an illegal arrangement, then unilateral reform by the U.S. is the best outcome for the EU and unilateral reform by the EU is approximately tied as the best arrangement for U.S. welfare.

*Table 6.12. Welfare of the EU and the U.S. Under Alternative Institutional Arrangements.*

| | EU welfare million dollars | U.S. welfare million dollars |
|---|---|---|
| Base Solution | 241.80 | 401.64 |
| Unilateral reform by EU | 176.61 | 554.74 |
| Unilateral reform by U.S. | 301.49 | 363.39 |
| Free trade | 219.07 | 555.51 |
| GATT outcome | 237.89 | 470.99 |

The improvement of U.S. welfare under free trade explains well its initial willingness to fully eliminate export subsidies. In fact, the level of U.S. welfare in free trade is practically the same as in the case when EU unilaterally eliminates its export subsidies. However, for the EU only the case in which it unilaterally reforms export subsidies results in a worse outcome than under free trade. The qualitative effects of the actual GATT outcome are the same as in free trade, but smaller in magnitude.

A question that arises is why did the EU agree to reduce its export subsidies when effects are welfare reducing? The crucial factor so far ignored in our analysis is the MacSharry CAP reform, which lowered marginal costs of the EU exporting firm by 30 percent. Recall that the one of the results of CAP reform scenario was that the EU considerably decreased its export subsidies, but the subsidy set by the U.S. was actually slightly increased. In fact, it was shown that as a result of CAP reform the export subsidy set by the U.S. ($36.46 per ton) increased enough to exceed the export subsidy set by the EU ($32.90 per ton) (see Table 6.6).

When we now analyze effects of export subsidy constraints (set by the GATT agreement) in these circumstances, very different results arise. Comparisons are made between the pre-GATT scenario and the GATT outcome scenario after CAP reform has already occurred.

The GATT agreement requires that export subsidies are reduced by 49 percent and 57 percent for EU wheat and U.S. wheat, respectively, from their base levels, where the base levels are the subsidies at the time before CAP reform (our base solution). Therefore, the GATT upper bound for the export subsidy of U.S. wheat is $15.03 per ton (0.43 times $34.95 per ton), and the upper bound for the export subsidy of EU wheat is $40.58 per ton (0.51 times $79.57 per ton). After CAP reform the pre-GATT equilibrium export subsidies were $36.46 per ton for U.S. wheat and $32.90 per ton for EU wheat. Therefore, it seems that only the GATT constraint for U.S. wheat is binding. To see if the upper bound on EU wheat has any effect on the behavior of the EU (or the

U.S.), we study a case in which the EU sets its subsidy (while ignoring the GATT upper bound on EU wheat) to maximize its discounted future welfare given that the export subsidy for U.S. wheat is fixed to the binding GATT upper bound. Exporting firms set their prices as before. The outcome of this scenario shows that the export subsidy of EU wheat would have been $49.01 per ton, implying that the GATT upper bound on EU wheat is also binding. For U.S. wheat, the GATT constraint is clearly binding since, given that EU subsidizes at its GATT upper bound, the unconstrained U.S. export subsidy would have been $53.81 per ton, in contrast to $15.03 per ton allowed by the agreement. Therefore, the scenario that illustrates the actual GATT outcome has upper bounds binding for both countries[19].

Table 6.13 shows the effects of GATT agreement on wheat trade to Morocco when impacts of the CAP reform are also taken into account. As was noticed, the upper bound on the export subsidy is much more restrictive for U.S. wheat than it is for EU wheat. In fact, the EU exporting firm receives higher subsidies than before the GATT agreement. The higher subsidy allows the EU firm to behave more aggressively. This enhances price competition between exporting firms, so much that, maybe somewhat surprisingly, no price increase occurs. In contrast, the U.S. wheat price falls from $162.69 per ton to $161.25 per ton, and the EU wheat price falls from $173.68 per ton to $163.96 per ton.

Since a larger cut occurs in the price of EU wheat than in the price of U.S. wheat, the EU is able to capture substantial market share from the U.S. in the Moroccan market. EU exports, therefore, increase from 86.58 thousand tons to 103.56 thousand tons, and U.S. exports are reduced from 134.00 thousand tons to 115.73 thousand tons.

In the case of EU wheat, the large increase in export volumes to Morocco outweigh the reduction in price and increase in export subsidy expenditures, improving welfare of the EU. Thus, these simulation results are consistent with the notion that the CAP reform was an important element in the process to reach GATT agreement in export subsidy reductions.

[19] Note that in the early years of the GATT implementation period upper bounds have not been binding. As mentioned earlier in this chapter, this can be explained by changes in the governments' objectives to be more concerned about budgetary costs of farm programs. In addition, global grain production between 1993/94 and 1995/96 remained lower than its 1992 peak, with some of the major exporters experiencing below-normal crops. Meanwhile, demand for grains continued to increase, reflecting robust economic growth in many countries, especially in Asia. For three consecutive years, global wheat consumption surpassed production, resulting in the lowest grain stocks in 20 years. World wheat prices increased sharply to unusually high levels, and so there has not been the need for export subsidies during the first GATT implementation years. The scenario presented in the text assumes that final GATT upper bounds are binding at the end of the implementation period.

*Table 6.13. Impacts of Uruguay Round GATT Agreement on the European Union and the United States When the MacSharry CAP Reform is Taken Into Account.*

| | Base solution | After CAP reform | GATT Outcome with CAP reform |
|---|---|---|---|
| U.S. price ($/ton) | | | |
| steady state | 165.90 | 162.69 | 161.25 |
| U.S. exports (1000 tons) | | | |
| steady state | 137.31 | 134.00 | 115.73 |
| U.S. export subsidy ($/ton) | | | |
| steady state | 34.95 | 36.46 | 15.03 |
| U.S. welfare (million dollars) | | | |
| total discounted future welfare | 401.64 | 382.86 | 344.77 |
| U.S. firm's profits (million dollars) | | | |
| total discounted future profits | 184.48 | 175.86 | 104.20 |
| EU price ($/ton) | | | |
| steady state | 179.74 | 173.68 | 163.96 |
| EU exports (1000 tons) | | | |
| steady state | 81.56 | 86.58 | 103.56 |
| EU export subsidy ($/ton) | | | |
| steady state | 79.57 | 32.9 | 40.58 |
| EU welfare (million dollars) | | | |
| total discounted future profits | 241.80 | 271.90 | 299.04 |
| EU firm's profits (million dollars) | | | |
| total discounted future profits | 109.43 | 123.05 | 143.14 |

### 6.4.3. Effects of Firm Behavior

Chapter II provided some evidence on the imperfectly competitive nature of wheat exporting firms. The wheat export industry was described as at least moderately concentrated, and large exporting firms may have some degree of market power. However, the magnitude of the exporting firms' market power is quite small, and it is exporting countries governments instead of firms that exercise the greatest power on the market.

The base solution of our empirical model is constructed in such a way that two wheat exporting firms, one from each exporting country, play a price setting duopoly game. Since the market power that exporting firms exercise in international wheat trade is said to be quite small, it is possible that the duopolistic modeling framework might assign too much market power to exporting firms. Therefore, the purpose of this section is to analyze how the different degrees of market power of exporting firms affect market outcomes. Four alternative scenarios are compared with the base solution. One scenario examines perfectly competitive behavior of firms. The second scenario illustrates the case in which a cartel of two exporting firms maximize their joint profits. The last two scenarios describe how timing in decisions affect on market agents' market power. Simulation results are shown in Table 6.14.

### 6.4.3.1. Perfectly Competitive Firms

In the case of perfectly competitive firms it is assumed that competition between firms that export EU wheat drives the price of exported EU wheat down to firms' marginal cost. Similarly, the U.S. firms set their prices equal to U.S. marginal cost. Therefore, firms are making zero profits, as can be seen from Table 6.14.

Since the influence that exporting firms in the base solution had on prices is gone, Morocco is buying more wheat at much lower prices. The price of U.S. wheat ($165.9 per ton in the base solution) falls to $103.83 per ton when firms

*Table 6.14. Impacts of Different Levels of Firm Market Power on the European Union and the United States.*

| | Base Solution | Perfectly competitive firms | Firm cartel | Ex post game | Simultaneous move game |
|---|---|---|---|---|---|
| U.S. price ($/ton) | | | | | |
| steady state | 165.90 | 103.83 | 181.86 | 236.27 | 123.19 |
| U.S. exports (1000 tons) | | | | | |
| steady state | 137.31 | 178.60 | 137.61 | 100.58 | 163.68 |
| U.S. export subsidy ($/ton) | | | | | |
| steady state | 34.95 | 26.17 | 232.68 | 469.41 | 79.48 |
| U.S. welfare ($million) | | | | | |
| total discounted future welfare | 401.64 | 322.85 | 273.09 | 153.49 | 300.72 |
| U.S. firm's profits (million) | | | | | |
| total discounted future profits | 184.48 | 0.00 | 736.25 | 1098.68 | 225.77 |
| EU price ($/ton) | | | | | |
| steady state | 179.74 | 106.84 | 203.04 | 266.58 | 128.72 |
| EU exports (1000 tons) | | | | | |
| steady state | 81.56 | 86.11 | 70.81 | 67.56 | 86.48 |
| EU export subsidy ($/ton) | | | | | |
| steady state | 79.57 | 83.16 | 344.12 | 544.47 | 126.41 |
| EU welfare (million) | | | | | |
| total discounted future welfare | 241.80 | 136.58 | 124.09 | 110.98 | 147.71 |
| EU firm's profits (million) | | | | | |
| total discounted future profits | 109.43 | 0.00 | 484.08 | 802.76 | 110.89 |

are perfectly competitive. The reduction in the EU wheat price is 3 percent larger than the U.S. price. One reason for the larger change in the EU wheat price is switching costs. Since the market power of exporting firms over the buyer does not exist anymore, effects of switching costs on governments behaviors are strengthened. Costs of switching away from U.S. wheat are higher than costs of switching away from EU wheat. Another reason is that import demand for U.S. wheat is more sensitive to own-price changes than import demand for EU wheat. This means that if the price of U.S. wheat and EU wheat are lowered by the same amount imports of U.S. wheat to Morocco increase more than imports of EU wheat. Therefore, the U.S. is able to capture a larger portion of the market than in the base solution. The U.S. is able to do this even though its export subsidy is $8.78 per ton less than in the base solution. In contrast, the EU has to subsidize its wheat exports more in order to prevent too large a drop in its market share. The export subsidy of EU wheat rises from $79.57 per ton to $83.16 per ton.[20] However, while the EU loses some market share it is still able to export more than in the base solution, because of the large reduction in the price level.

Both exporting countries are worse off with perfectly competitive firms. For the EU, this is easily seen: much lower price together with somewhat higher export volumes decrease export revenues. This is combined with increased export subsidy expenditures. Thus, EU welfare is reduced by 44 percent. For the U.S., export subsidy expenditures are decreased. However, the low price reduces export revenues despite increased export volumes. This reduction in export revenues exceeds the positive effect of savings in subsidy expenditures, leading to the smaller U.S. welfare than in the base solution.

#### 6.4.3.2. Firm Cartel

In the case of a firm cartel, wheat exporting firms are maximizing their joint profits. The formation of the cartel results in a smaller volume of EU wheat exports – from 81.56 to 70.81 thousand tons – and a higher price received for those exports – from $179.74 per ton to $203.04 per ton. The price of U.S. wheat is increased as well, but not to the same extent as the price of EU wheat. So, both prices that Morocco faces now are higher than in the base solution, leading to the smaller amount of total wheat imports. Since U.S. wheat now costs less relative to EU wheat, Morocco switches to purchase a larger portion of its wheat imports from the U.S.. Therefore, even though Morocco imports less wheat in total, the amount of U.S. wheat imported is basically the same as (in fact, slightly higher than) in the base solution.

[20] In the model without switching costs both exporting countries clearly reduce their level of export subsidies.

The effect of the formation of the wheat exporting cartel on export subsidies is substantial. Compared to the base solution, exporting firms now have much more market power. By cooperating they are able to extract massive export subsidies from both exporting countries. The U.S. government awards subsidies that are almost seven times as high as before, and the EU provides export subsidies that are more than four times as large as in the base solution. Naturally, with export subsidies of this magnitude governments are worse-off.

From the cartel members point of view considerable improvement has occurred. A relatively small decrease in total exports is companied by large increases in prices and enormous increases in export subsidies received from the governments of exporting countries. Profits of the U.S. firm are approximately four times the base solution profits, and for the EU firm profits are over four times as high as in the base case. However, the formation of a cartel is prohibited by antitrust laws of both the EU and the U.S. Therefore, the exporting firm cartel is unlikely to occur unless a form of tacit collusion takes place. In addition, it would not be possible for political reasons to maintain such high export subsidies.

Welfare levels of exporting countries in the first three scenarios are compared. Both exporting countries benefit the most in the base solution. If the imperfectly competitive market structure at the firm level is fully eliminated, then exporting countries are worse off. This is because in the base case exporting firms with some degree of market power were able charge a higher price, benefiting their governments as well. However, in the cartel scenario exporting firms' market power is maximized, and this enables them to extract very large export subsidies from governments, making governments again worse off. Therefore, it seems that some degree of firm level market power is good for the exporting country's welfare, but in contrast, the worst case for the exporting country's welfare occurs when too much market power is given to the exporting firms.

#### 6.4.3.3. Order of Play

##### 6.4.3.3.1. Ex Post Game

Another matter effecting firm level market power is timing in decisions. In most of our analysis so far, governments are assumed to move before firms in each period[21]. However, the wheat export subsidy program in the U.S. and in the EU that allows firms to bid for export subsidies seems to suggest the reverse order. Exporting firms negotiate a price in the importing country first and then request a subsidy from their government. In this sense, the subsidy is given ex post.

[21] This timing issue was also discussed in the base solution section of this chapter.

Since in this so called ex post game, firms are the first-movers (Stackelberg leaders in each period), they have even more market power than in the game where governments are the first-movers (ex ante game).

With the help of a simplified theoretical one-period model (without switching costs) it is shown in Appendix D that export subsidies, prices paid by an importing country, and profits of exporting firms are higher in an ex post game than an ex ante game. Export volumes and exporting country welfares, on the other hand, were shown to be lower than in the ex ante game. Results of our empirical multi-period switching cost model are consistent with these results. As Stackelberg leaders, the exporting firms' positions in the market are very strong. They are charging much higher prices than in the base solution. Price paid by Morocco on U.S. wheat is 42 percent higher and the EU wheat price is 48 percent than in the base solution. In addition, exporting firms are able to extract enormous export subsidies from their governments. The export subsidy of U.S. wheat is more than twice as high as the subsidy level of the ex ante game in which firms behave collusively. On the EU side, the exports subsidy is 58 percent higher than in the ex ante game with a firm cartel.

Naturally, high price levels imply a reduction in Moroccan wheat imports. U.S. wheat exports to Morocco are 36.73 thousand tons (27 percent) smaller than in the base case, and EU exports are reduced by 14 thousand tons (17 percent). From the exporting countries point of view, very large export subsidy expenditures clearly outweigh the increases in export revenues. Therefore, exporting countries are worse off in the ex post scenario than in the base solution. Obviously, the benefits are captured by the exporting firms. This can be seen from profits levels that are six and seven times as large as in the base solution for the U.S. firm and the EU firm, respectively.

Earlier in this chapter it was shown that the ex post model greatly exaggerates the level of market power that exporting firms have. In comparison with actual data, the ex post model suggested prices that were almost twice as high as actual prices. Exports volumes were lower than what is observed, and the levels of export subsidies that they extract from the governments were empirically unacceptable. Since the empirical model with ex ante (governments moving first) structure of the game performed much better, we have used it in our analyses instead of the ex post game. It is also important to keep in mind that if the firms behave perfectly competitively, then the order of decisions becomes irrelevant, since firms always set their prices equal to their marginal cost.

#### 6.4.3.3.2. Simultaneous Move Game

In our base solution game, exporting countries' governments were first-movers, and in the ex post game they were followers. In order to complete the discussion on order of play, the final scenario explores a game in which no one is a leader (or follower). That is, in each period exporting countries' governments and exporting firms set their strategic variables (export subsidies and prices) simultaneously.

In the preceding section it was shown that the ex post game's ability to describe observed behavior in the Moroccan wheat market was much worse than the base solutions' ability. In this section we examine how market agents' behaviors differ under this third alternative institutional arrangement (i.e., a simultaneous move game structure) and how well this game structure performs in describing observed behavior in comparison with the previous two game structures.

Since in the simultaneous move game exporting countries' governments are no longer leaders, they have less market power than in the base solution (ex ante game). This means that both U.S. government and EU government award larger export subsidies than in the base solution. The export subsidy of U.S. wheat is increased from $34.95 per ton to $79.48 per ton while the export subsidy of EU wheat is increased from $79.57 per ton to $126.41 per ton. Exporting firms' market power, on the other hand, has changed very little from the base solution. Therefore, the additional export subsidies that exporting firms now receive from their governments are mostly transferred to wheat prices. The price paid by Morocco on U.S. wheat is $42.71 per ton lower in the simultaneous move game than in the base solution and the reduction in the EU wheat price is $51.02 per ton. These lower prices imply that Morocco is able to buy more of both wheats. However, a much larger increase occurs in exports of U.S. wheat (19 percent increase) than in exports of EU wheat (6 percent increase). This is because Moroccan import demand for U.S. wheat is more sensitive to own-price changes than is Moroccan import demand for EU wheat.

Both exporting countries' governments are worse off under the simultaneous move game scenario than in the base solution. Although wheat exports to Morocco are increased, the considerably lower prices reduce export revenues for both exporting countries. In addition, much higher export subsidy expenditures take place. Wheat exporting firms, on the other hand, are able to capture larger profits than in the base solution. This is because they are exporting larger amounts of wheat with approximately the same total price (price paid by Morocco + export subsidy) as in the base solution. The increase in the U.S. firm's profits (22.4 percent) is larger than the increase in the EU firm's profits (1.3 percent) because exports of U.S. wheat are increased more than exports of EU wheat.

When simultaneous move game is compared with ex post game it can be seen that simultaneous move game provides results which are much closer to actual behavior. However, the base solution (ex ante game) outcome is still preferred over the simultaneous move outcome, as it captures more accurately observed behavior.

## 6.5. Conclusions

Several tasks were accomplished in this chapter. Additions and modifications needed to make the previously created theoretical framework empirically applicable were presented. The chapter provided the base solution of the empirical model, whose predicted values of the endogenous variables were compared to actual values (Table 6.2). Finally, the empirical model was used to analyze effects of changes in the economic environment.

On average, model solutions were consistent with observed data. However, prediction errors occurred because domestic production and consumption of wheat in the exporting countries were not included in the model. Therefore, effects of changes in the domestic production and consumption levels on trading behavior were not captured by this empirical model. Another reason why prediction errors arose is because the model assumed that the governments' objective functions have the same structure in each time period. However, in reality values in the governments' objective function are changing over time. Since such changes in the governments' objective functions are not captured by the empirical model, it limits the model's ability to describe long term actual behaviors when such changes take place in the market.

When effects of changes in the economic environment were analyzed, it was first shown that switching costs caused the EU and the U.S. to compete more aggressively. Higher export subsidies were awarded by exporting countries and lower prices were set by exporting firms than in the absence of switching costs. Exporting countries' incentives to increase market share dominated their incentives to exploit current market share, and so led to lower prices and higher export subsidies in markets with switching costs than in markets without switching costs. Hence, the introduction of switching costs to the modeling framework provided an intuitively appealing explanation why market share is often emphasized as a goal and a measure of successful export performance.

On the other hand, the opportunity cost of public funds had an opposite effect on U.S. wheat and EU wheat exports. When the opportunity cost of public funds was increased, attractiveness of export subsidies as a trade policy tool was reduced. Thus, exporting countries are less willing to get involved in a tough subsidy war when the opportunity cost of public funds is high.

Analysis of alternative institutional arrangements showed that noncooperative behavior of the EU and the U.S. has resulted in a problematic situation in which unilateral elimination of the export subsidy program is always the worst scenario for the country that eliminates its subsidies. The results also provided some insight for the often suggested link between the MacSharry CAP reform and actual GATT agreement. Without the CAP reform, constraints on export subsidies set by GATT would have been welfare reducing for the EU (in its wheat trade to Morocco). However, CAP reform resulted in a large decrease in marginal costs of EU wheat exporting firms, and so, made EU wheat more competitive in the Moroccan wheat market. Consequently, GATT restrictions in export subsidies became less binding on the optimal behavior of the EU. Therefore, these results were consistent with the notion that CAP reform was an important element in the process of reaching GATT agreement in export subsidy reductions.

The last set of scenarios studied the effects that firm level market power has on behaviors of the EU and the U.S. It was shown to be important for both the EU and the U.S. to be able to prevent formation of an exporting firm level cartel. In cooperation exporting firms can (in theory) extract very large export subsidies from the governments of exporting countries, making the exporting countries worse off. However, some degree of firm level market power seems to be welfare improving for the exporting countries, since with market power exporting firms are able charge higher price for their wheat than in the case of perfectly competitive firms. When this positive effect of higher price received for the exported wheat exceeds the negative effect of exporting firm extracting higher export subsidies from the government, then exporting countries should prefer an imperfectly competitive firm level market structure over a perfectly competitive market structure.

When timing in decisions was reversed (from ex ante game to ex post game), exporting firms position became very strong in the market. As Stackelberg leaders, they were simultaneously able to charge high wheat prices and extract very large export subsidies at the expense of the importing country and of exporting countries' governments. When the comparison between ex post game results and actual data was made, it was clear that the ex post model greatly exaggerated the level of market power that exporting firms have.

# CHAPTER VII

## SUMMARY, CONCLUSIONS, SUGGESTIONS FOR FUTURE RESEARCH

The European Union and the United States were described as two noncooperatively behaving "super-powers" in the international wheat market, whose actions in the market have an influence on each other's agricultural policies as well as on world market prices. The most significant strategic variable for these countries has been an export subsidy, reflecting the producer bias of trade policy. Subsidized exports of EU and U.S. wheat are sold abroad by large exporting firms, and some evidence was provided that firm level price competition is oligopolistic (imperfect) in nature.

Another important aspect of international wheat trade is the behavior of an importing country. Several factors affect an importing country's purchasing decisions. The price of the product is an obvious, and often the most important, factor. However, in reality it is very seldom observed that an importing country purchases all of its wheat imports from the least expensive supplier, as is suggested by traditional spatial equilibrium models. Another factor affecting an importing country's decision to buy wheat is the quality of wheat. For example, qualitative characteristics of EU wheat and U.S. wheat are different, requiring a model of product differentiation to be used when market behavior is studied.

One general group of factors that also affects an importing country's purchasing decisions is called *switching costs*. These costs of switching from one wheat exporter to another, which are borne by the importing country, might exist for many reasons. An importer incurs costs when negotiating a contract or agreement with a supplier, and these transactions costs with a new exporter may be higher than with an existing exporter.

Another category is learning costs. There is more risk involved when buying from a new, unfamiliar source than when buying from an existing supplier. There also might exist political costs of switching between exporters. One would expect products supplied by political allies to be viewed differently from others. In addition, guaranteed credit programs and government relationships can induce switching costs.

Armington-type trade models have been developed to account for features that differentiate commodities according to country of origin. These models exhibit much smoother changes in trade shares than the traditional spatial equilibrium model, and account more adequately for observed trade flows than the traditional spatial equilibrium model. However, one problem with Armington-type trade models is that they are static models in which the differentiation between wheat suppliers is captured using a constant elasticity of substitution parameter. Effects of switching costs, on the other hand, are dynamic in nature, and in order to capture those effects a dynamic modeling framework is needed.

Agricultural trade modeling literature was reviewed in Chapter III. It was recognized that game-theoretical methods, which allow us to incorporate strategic interactions between players in the market, have been used in the more recent literature (e.g., Paarlberg and Abbott (1986), Thursby and Thursby (1990)). However, the majority of these studies used static models in their analysis, even though in practice, firms and governments are interacting repeatedly. The most commonly used approach has been conjectural variations, which has been criticized (e.g., Tirole 1988) as an ad hoc way to model dynamic features in a static framework. In order to introduce switching costs into the conceptual framework an explicitly dynamic modeling approach becomes necessary. So far, a very limited number of dynamic, game theoretic agricultural trade studies exist (e.g., Karp and McCalla 1983, McNally 1993), and none of them have employed the switching cost approach.

The first objective of this study then was to develop a dynamic, game theoretic model of the international wheat market that incorporates strategic interactions among players who exercise market power, and that simultaneously captures the impacts of switching costs on players' strategies. This was accomplished in two stages. First, a theoretic two-period model of oligopolistic competition with differentiated products and switching costs was constructed. The model was developed such that the importing country faced no switching costs in the first period, but developed switching costs as a result of its first-period purchases, so exporting countries and firms had some additional market power in the second (final) period. In each period, the exporting country governments simultaneously chose their export subsidies (taxes if negative) to maximize domestic welfare – defined as export revenues less export subsidy expenditures. Thus, from the political economy point of view this objective function was weighted towards domestic producers, since the weight on domestic consumer surplus was set to zero. After that, firms in both exporting countries simultaneously set their prices to maximize profits.

It is important to keep in mind that this model is a so called third-market model in which exporting countries (the EU and U.S.) and their exporting firms compete only in a single third market (Morocco). This simplification was useful in allowing the strategic effects of certain policy shocks to be seen in pure form. However, domestic wheat production, stocks and consumption of exporting countries were not included in the model. So, one way to describe the settings under which the model operates is the surplus disposal concept. That is, both exporting countries hold very large amounts of wheat that need to be either exported or stored, and magnitudes of wheat exported to one importing country do not provide much of relief to the overall pressure to export. So, under these circumstances when the government of each exporting country is awarding export subsidies to enhance wheat exports to the importing country, one reasonable form of its objective function would seem to be to maximize export revenues less costs of export subsidies. However, when impacts of policy shocks that may cause considerable changes in domestic production, stocks and/or consumption of exporting countries are analyzed, welfare effects of the model should be analyzed with care since those changes in domestic production, stocks and consumption are not captured by this model.

## 7.1. Theoretical Findings

The two-period model was explained in detail to highlight the theoretical effects that the introduction of switching costs has on the behavior of exporting countries (both firms and governments). It was found that exporting countries' governments awarded lower export subsidies (or increased export taxes) and exporting firms charged higher prices in the second period than in an otherwise identical market without switching costs. The reason was that each exporting firm now had an incentive to exploit the importing country that, due to switching costs, had become partly locked in to the firm as a supplier. Higher prices implied that lower export subsidies were needed. In addition, the results supported the intuition that export subsidies (export taxes) were lower (higher) and prices were higher than in the initial period, in which the buyer had not yet become attached to any wheat supplier. These results are consistent with the results of To (1994).

It was not possible to unambiguously show, however, that either an export tax or an export subsidy in the second period is always the optimal policy for the government of the exporting country without empirically analyzing the market. This differed from To's (1994) proposition, "in the second period both countries set export taxes", because the government's objective function in his model is different from the one used in this research. In To's model government maximizes the domestic firm's profit level plus tax revenues, whereas in our model the government's objective was designed to capture producer bias in agricultural policy.

Our model suggested that the smaller the wheat sector's marginal costs were, the more likely it was that an export tax would have been the optimal policy in the second period. In addition, an exporting country was more likely to set an export tax as the optimal policy when its first period exports were large and marginal switching costs were high, because in this case the importing country was tightly locked in to the exporting country.

Switching costs implied that second-period prices, profits and exporting countries' welfare were increasing, and export subsidies were decreasing in first period market share, while in the absence of switching costs there was no connection between the markets in periods 1 and 2. Since exporting firms' second-period profits and exporting countries' second-period welfares depended on first-period exports, switching costs made exporting countries compete more aggressively for market share in the first period than they would have if they were simply maximizing first-period profits and welfare. Hence, market shares matter, providing an explanation for the emphasis placed, by USDA for example, on market share as a measure of export performance. The more aggressive competition on market shares implied that first-period prices, profits and exporting countries' welfares were lower and export subsidies were higher than in a market without switching costs. In fact, it was even possible that in order to capture a larger market share in the first period, dumping could have become a rational behavior of the exporting firm.

This two-period model can be seen as an alternative framework to To's model to analyze strategic trade policy in the market where switching costs exist. Some of the other differences between our model and To's (in addition to the alternative government objective function) were that our model explicitly included switching costs in the model and, while To assumed Hotelling consumer demand, we derived a linear demand structure from a quasilinear utility function. The main motivation to provide this alternative method was its more appropriate form for empirical implementation in the case of international wheat trade. Empirical application of the model with switching costs was needed in order to better analyze effects that changes in the economic environment have on players' behaviors in that market.

Two-period models are not the most satisfactory for analyzing the effects of policy shocks or other shocks in the economic environment, since in the real world we have more than two periods and any given period is not really well classified as either a first or a second period, but as some intermediate period which is not without switching costs. Therefore, the second task was to extend the two-period model into a more general finite-horizon multi-period model of competition in a market with switching costs. Other generalizations of this empirical multi-period model included more general (though linear) import demand functions, asymmetric marginal costs and the introduction of opportunity costs of public funds to capture the fact that raising tax revenues to cover export subsidy expenditures incurs administrative costs and creates distortions in other sectors of the economy.

## 7.2. Empirical Findings

The next step in this research was to econometrically estimate import demand functions for the empirical model. Since in the case study of this dissertation competition between EU and U.S. wheat in Morocco was analyzed, Moroccan import demand functions for EU and U.S. wheat needed to be estimated. Two main reasons for re-estimation of these import demand functions arose. First, this study differed from most earlier studies that estimated behavioral equations in international wheat trade in that monthly data instead of annual data were used in the estimation. Monthly data were preferred because strategic interaction between players in this market happens on a transaction by transaction basis, and one important goal of this research was to capture that behavior.[1] Use of annual data would have concealed much of the strategic interaction occurring in this market as well as much of the price responsive behavior by the importing country. Another reason for econometric estimation was to analyze the statistical significance of switching cost parameters in order to validate our new agricultural trade modeling approach.

Econometric estimates of import demand functions suggested that switching costs exist in the Moroccan wheat import market. They further suggested that costs of switching away from U.S. wheat were larger than costs of switching away from EU wheat, meaning that somehow the U.S. has been able to lock in Morocco more tightly to itself than the EU was able to do. Also, when the own-price and cross-price import demand elasticities were compared with those of previous studies, it was found that this study provided more elastic estimates. One important reason for more elastic price elasticity estimates was that the monthly data reflected better the more price sensitive behavior of the importing country than commonly used annual data do.

In chapter VI several different scenarios were performed and results were compared to a base solution of the empirical model (which corresponded roughly to the pre-GATT situation). One group of scenarios analyzed the effects that changes in key parameter values have on the behaviors of exporting firms and exporting countries. In particular, effects of switching costs and of opportunity costs of public funds were studied. In addition, effects of different degrees of product differentiation, of different marginal costs and of parameter asymmetries were analyzed.

In a multi-period framework with switching costs, exporting countries in each period face a tradeoff in which they can either exploit their current market shares with higher prices and lower export subsidies or compete for larger market shares with lower prices and larger subsidies. Beggs and Klemperer (1992) state that we should expect firms' incentives to exploit current market share to dominate their incentives to increase market share that could be exploited later, and so lead to higher prices in markets with switching costs than in markets without switching costs. This research answers two questions that follow from Beggs and Klemperer:

- Do exporting firms charge higher prices and collect larger rents when switching costs exist in international wheat trade?
- Is the need for export subsidies smaller when switching costs exist in the international wheat market?

[1] In fact, daily or transaction-by-transaction data is preferred but was not available.

In contrast to presumption of Beggs and Klemperer, the results of this study indicated that exporting firms charge lower wheat prices and higher export subsidies are awarded by governments of exporting countries when switching costs are present. Therefore, with switching costs the exporting countries competed more aggressively on the Moroccan wheat market. Asymmetry in estimated marginal switching cost parameters in favor of U.S. wheat made the U.S. exporting firm able to earn larger profits and the EU exporting firm to earn smaller profits than without switching costs.

Abbott et al. (1987) found that a targeted export subsidy program, like EEP, can be welfare improving because it allows an exporting country to price discriminate. By subsidizing relatively elastic markets, the exporting country is in effect taxing countries with relatively less elastic excess demand schedules. Switching costs make a repeat-purchaser's excess demand more inelastic. This means that heavier subsidization may be required by an exporting country to increase its market share in a market with switching costs.

The empirical model also provides answers to following research questions:

- Do switching costs make the EEP more costly than without consideration of these costs?
- If switching costs make a targeted subsidy program's costs higher, does the unilateral termination of the EEP in a market with switching costs then become a more attractive export policy choice for the U.S. government than in a market without switching costs?

With switching costs, the higher per unit export subsidy led to lower price of U.S. wheat than in the market without switching costs. This made U.S. wheat more attractive to Morocco, resulting in an increase in U.S. wheat imports to Morocco. From the trade policy perspective, this suggests that costs of export promotion programs may be higher than often expected. The United States introduced the EEP program in 1985 to gain market share in the world wheat market. If the USDA did not take into account switching costs in its calculations, our results indicated that in markets like the Moroccan wheat market costs from the EEP bonuses for the budget of the U.S. government would have been underestimated.

Switching costs did not make it more attractive for the U.S. to unilaterally eliminate its export subsidy program, however. This is because in the market with switching costs market shares matter more than in a market without them. Therefore, even after unilateral elimination of export subsidies by the U.S. the EU continued to aggressively subsidize its wheat exports in order to capture more market share. Therefore, unilateral elimination of export subsidies by the U.S., in the market like the Moroccan wheat market where switching costs appear to exist, would have resulted in a larger decrease in export volumes accompanied by lower prices paid by the importing country than in a market without switching costs.

The results further showed that the exporting country and the exporting firm clearly benefit from the increased importer's costs of switching to rival's wheat. Because of these benefits, exporting countries have incentives to exercise trade policies that would help to create switching costs. Some kinds of switching costs can be seen as the result of deliberate exporting country actions. For example, exporting countries' guaranteed credit programs may be seen as one way to create switching costs, since a loan under guaranteed credit program can only be used to purchase wheat from the country who provides the credit guarantees for that loan.

Market shares are a commonly used measures of export performance. Gehlhar and Vollrath state that the U.S. Department of Agriculture, for example, uses market shares as an indicator of export performance. They also say that because of the association between export performance and market share, the loss in U.S. agricultural market share concerns policymakers. The empirical model of Moroccan wheat import market was able to provide some insight into this importance attached to market shares by exporting countries. If an exporting country is able to increase its market share, this creates additional costs for the importing country (Morocco) to switch away from that exporting country's wheat in the future. Each exporting country and each exporting firm realize this. Therefore, their behaviors are not just driven by maximization of current period welfare (exporting country) and profits (exporting firm), but also by the desire to increase current market share which could improve future welfare of that exporting country and future profits of the exporting firm. Hence, the notion of switching costs in the market provides an intuitive explanation why exporting countries and firms are often concerned with market share in addition to short run welfare and profits.

The results of one group of scenarios illustrated effects of the opportunity costs of public funds. When the additional welfare costs of public funds were ignored, then the U.S. government as well as the EU government was more willing to use large export subsidies as a policy tool than in the case in which there existed additional costs of public funds. Therefore, the two superpowers engaged in a more severe subsidy war when fighting over market shares in the Moroccan wheat market. This excessive use of subsidies led to a reduction in total discounted future welfare of each exporting country. On the other hand, exporting firms' total discounted future profits improved.

The higher the opportunity costs of public funds were, the more conservatively both exporting countries were in awarding export subsidies. This implied that higher prices were charged by exporting firms and export volumes were smaller. Since attractiveness of export subsidies as a policy tool was diminished, exporting countries did not get involved in as tough a subsidy war game. Therefore, total discounted welfare of these countries increased. Strongly increased budgetary concerns of the EU and the U.S. in recent years can be seen as increased opportunity costs of public funds, and so provides a partial explanation for reduced export subsidies by the EU and the U.S. in international wheat trade.

Econometric estimations in Chapter V showed that EU wheat and U.S. wheat were imperfect substitutes in the Moroccan wheat market. When the effects of product differentiation were further examined, familiar results from the industrial organization literature arose. An increase in product differentiation gave more market power to the exporting side by reducing price competition among exporting firms and export subsidy competition between governments. Greater product differentiation led to both exporting firms charging higher prices and both exporting country governments providing lower export subsidies than in the base solution. These findings implied that total discounted profits of exporting firms increased. Thus, the results are consistent with static theoretical Bertrand (as well as Cournot) games with product differentiation, which say that the profits of firms increase when the products become more differentiated.

Another group of scenarios illustrated how the alternative institutional arrangements (game structures) in international wheat trade change the levels of export subsidies (or taxes), prices, export volumes, and the payoffs for four players: the EU, the U.S., the EU wheat exporting firm, and the U.S. wheat exporting firm. A free trade scenario and the outcomes when either the EU or the U.S. unilaterally reforms by eliminating its export subsidies were considered. Collusive behavior by EU and U.S. governments was also examined. Two different issues were examined regarding the Uruguay Round GATT agreement. The first looked at the effects of the final GATT outcome by imposing subsidy expenditure limits. The second issue analyzed how the welfare effects of new GATT agreement differ when effects of CAP reform were taken into account. [2]

Analysis of alternative institutional arrangements showed that noncooperative behavior of the EU and the U.S. has resulted in a problematic situation in which unilateral elimination of the export subsidy program is always the worst scenario for the country that eliminates its subsidies. The improvement of U.S. welfare in the free trade case explained well its initial willingness to fully eliminate export subsidies. In fact, it was found that the level of U.S. welfare in free trade was practically the same as in the case when EU unilaterally eliminated its export subsidies. However, for the EU only the case in which it unilaterally reformed export subsidies resulted in a worse outcome than under free trade.

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[2] Whenever welfare effects of different scenarios are discussed in here, it is important to keep in mind that the empirical model is a third-market model in which the EU and U.S. and their exporting firms compete only in the single third market, Morocco. Therefore, the results of different scenarios are not meant to be global assessments of alternative institutional arrangements, but instead illustrate their impacts on exporting country behavior in the one importing country market.

The cartel arrangement between policymakers for the EU and the U.S. allowed the exporting countries' governments to capture almost all of the market power. Thus, wheat exports were heavily taxed. Although, welfares of both exporting countries were higher than in any other institutional arrangement studied, the cartel's appearance is not very likely. Joint setting of export taxes by the EU and the U.S. is probably GATT-illegal, or at least politically incorrect.

These results suggest that if the Uruguay Round GATT agreement (reduction in export subsidies) had occurred before the EU's 1992 CAP reform, then the qualitative effects of the actual GATT outcome would have been the same as under free trade, but smaller in magnitude. However, the MacSharry CAP reform lowered marginal costs of the EU exporting firm due to the reduction in the EU's internal support prices. In response to the reduction of EU support prices, a major decrease occurred in the level of export subsidy that the EU government set. Although the EU government greatly decreased its subsidy level, it still provided a subsidy that kept EU wheat competitive against U.S. wheat in the Moroccan market. In fact, the combination of export subsidy (even though lower than before) and lower marginal cost made it possible for the EU exporting firm to charge a lower price than before CAP reform. The lower price allowed the EU to capture some market share from the U.S. Therefore, these findings suggested that the EU as well as its exporting firm benefited more from wheat trade to Morocco after the CAP reform than before it.

The impacts of the reduction in EU support prices on the U.S. were such that the U.S. exporting firm was now actually facing more severe price competition from its EU rival in the Moroccan wheat market. The U.S. firm was, therefore, forced to lower its export price. This lower price meant that the U.S. government had to provide larger EEP-bonuses for the exporting firm to keep U.S. wheat competitive in this import market. However, the reduction in the U.S. wheat price was still less than in the EU wheat price. Therefore, the U.S. lost a small portion of its market share. Since the price and exports of U.S. wheat decreased and export subsidy expenditures increased, the reduction in support prices of the EU made the U.S. benefit less from its wheat trade to Morocco. Also, the total discounted profits of the U.S. exporting firm were lower.

Since required GATT reductions in export subsidy levels were made from their pre-CAP reform base levels, MacSharry CAP reform helped to make the GATT upper bound for the EU export subsidy more acceptable. Thus, the simulation results of this research are consistent with the notion that MacSharry CAP reform was an important element in the process to reach GATT agreement on export subsidy reductions.

The final objective of this research was to use the empirical dynamic game model with switching costs to investigate effects that different levels of firm market power have on trade outcomes. It was shown to be important for both the

EU and the U.S. to be able to prevent formation of an exporting firm cartel. By cooperating, exporting firms could extract very large export subsidies from the governments of exporting countries, making the exporting countries worse off. However, some degree of firm level market power seems to be welfare improving for the exporting countries, because with market power, exporting firms are able to charge higher prices for their wheat than in the case of perfectly competitive firm. Thus, the results of this study suggest that when this positive effect of higher price received for the exported wheat exceeds the negative effect of exporting firm extracting higher export subsidies from their government, then exporting countries should prefer an imperfectly competitive firm level market structure over a perfectly competitive market structure.

In addition, timing in players decisions affects the degree of market power that each player has. In most of our analysis, governments were assumed to move before firms in each period. However, the wheat export subsidy program in the U.S. and in the EU that allows firms to bid for export subsidies seems to suggest the reverse order. Exporting firms negotiate a price in the importing country first and then request a subsidy from the government. In this sense, the subsidy is given ex post. An ex post scenario was presented to study effects of playing order.

When the order of the play is reversed, firms are the first-movers (Stackelberg leaders in each period), and they have more market power than in the game where governments are first-movers (ex ante game). The results here provide evidence that export subsidies, prices paid by an importing country, and profits of exporting firms are higher in an ex post game than an ex ante game. Export volumes and exporting country welfare, on the other hand, were shown to be lower than in the ex ante game. As Stackelberg leaders, the exporting firms' position in the market is very strong. It was also shown that the ex post model greatly exaggerated the level of market power that exporting firms appear to have in actual wheat trade. In comparison with actual data, the ex post model suggested prices that were almost twice as high as observed prices. Export volumes were lower than what is observed, and the levels of export subsidies extracted from governments were unacceptably high. The empirical model with ex ante (governments moving first) structure of the game performed much better in describing observed behavior.

In order to complete the discussion on order of play, a game in which no one is a Stackelberg leader (or follower) was studied. That is, in each period exporting countries' governments and exporting firms set their strategic variables (export subsidies and prices) simultaneously. When this simultaneous move game was compared with the ex post game it provided results which were much closer to actual behavior. However, the base solution (ex ante game) outcome was still preferred over the simultaneous move outcome.

It is also important to keep in mind that if the firms behave perfectly competitively, then the order of decisions becomes irrelevant, since firms always set prices equal to their marginal costs.

## 7.3. Suggestions for Future Research

This research produced several empirical as well as theoretical findings that improve our understanding of large exporting country behavior in the international wheat market. However, some problems with the empirical model presented in this dissertation emerged from the results presented in Chapter VI. Future researchers will need to consider these problems when using the framework developed here to study international commodity trade. First is the issue of firm level competition. The model assumed that one aggregate exporting firm exported wheat from each exporting country. That is, a duopoly structure was assumed at the firm stage of each period. Actually, there is more than one firm that exports EU wheat as well as U.S. wheat. Therefore, too much market power was assigned to exporting firms, implying higher prices than what we observe. On the other hand, in the absence of firm level market power, prices paid by Morocco were shown to be lower than observed prices, suggesting that international wheat exporting firms are not just price takers either.

Introduction of more than one firm selling each exporting country's wheat should be one area of future research. However, one problem with introducing several exporting firms is that it substantially complicates the model structure. Another problem is that more specific data would be required to do empirical analysis, and that data (e.g., each firm's marginal costs) may be very difficult to obtain. On the other hand, if it is assumed that all wheat exported from, for example, the U.S. is homogeneous good then all firms exporting U.S. wheat would be involved in price competition with homogeneous product. The Bertrand paradox states that price competition with a homogeneous good (and without capacity constraints) reduces prices to marginal costs, thereby making firms earn zero profits (i.e., this boils down to the perfectly competitive firm scenario presented in Chapter VI) (Tirole 1988). However, the Bertrand paradox can been solved by introducing capacity constraints for the firms. Kreps and Scheinkman (1983) show (in a particular two-period dynamic game) that for some market games where two firms choose how much to produce in period 1, and then set prices in period 2, a subgame perfect equilibrium yields the exact quantity produced and price as those in a one-shot Cournot game, where firms choose only how much to produce.

The second weakness of the model was the structure of the government objective function. The opportunity cost of public funds was assumed to be fixed over time. However in reality, values in the governments' objective function are changing over time. The lobbying power of different special interest groups does not stay the same. Farmers' ability as a special interest group to provide pressure on countries' trade policy decisions has been decreasing over time, more so in the U.S. than in the EU. An area of future research should be to develop a model which emphasizes two-way interaction between internal politics and international economic relations.

The third problem of the empirical model was that it did not explicitly include domestic wheat production, stocks and consumption of exporting countries. This limited the model's ability to describe long term actual behavior when considerable changes took place in these domestic factors. Another area of future research should be to improve linkages between domestic behavioral equations and trade decisions.

An improved understanding of the major players' behaviors in international wheat trade can have positive implications for future multinational trade negotiations as well as for individual trading countries. On the one hand, the better the motives for existing export promotion policies are understood, the better the starting point that is provided for future GATT negotiations. On the other hand, it can help the EU and the U.S. to identify implications that their own behaviors in international wheat trade have on each other's behaviors as well as how other major trading countries' decisions affect to them.

The research undertaken in this dissertation should be viewed as an effort to shed further light on behaviors of the European Union and the United States in international wheat trade. Switching costs provide an intuitive explanation why market shares matter as a measure of export performance. A large number of changes in economic environment were analyzed with the hope that a better understanding of strategic behaviors of the EU and the U.S. in international wheat trade has emerged, as well.

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## Appendix A. Supportive Numerical Analysis for the Comparative Statics Analysis of the Theoretic Two-period Model with Switching Costs.

We strongly believe that the comparative statics results shown in Chapter IV which explains the two period model are true unambiguously, but this belief does not mean much without providing a rigorous proof. Unfortunately, these analytical proofs are beyond our ability. We can derive the partial derivatives, $\partial S_1^i/\partial\eta > 0$, $\partial S_1^i/\partial\delta > 0$, but signing them analytically has proven to be a very difficult task. The only thing left then is to try to find as much support as possible for our comparative statics results through numerical analysis. Naturally, the use of numerical analysis is not a proof. However, if with numerous different values of parameters we are not able find a single counterexample for our statements, this could be interpreted as some degree of support for the comparative statics results given at the end of two-period model section in Chapter IV.

In the numerical analysis we need to look at results only in the relevant range of parameter values. The relevant range is drawn from the assumptions and conditions that need to be satisfied in the model: 1) all the parameters ( $a$, $b$, $e$, $\bar{\tau}$ , $\eta$, $c$, $\delta$) are positive, 2) $b>e$ and $\eta$ is small relative to $b$ and $e$, 3) $e^2 / b^2$ is not too close to zero, that is products are differentiated, but they are reasonably close substitutes[1] 4) prices and export volumes are positive, 5) $\bar{\tau}$ is small relative to prices, 6) the second order conditions for a firm's problem and for a government's problem in the first-period have to be satisfied, and 7) discounted total profits in the first period are nonnegative.

Given these relevant ranges of parameter values we then take numerous points for each parameter within these ranges. GAMS is used to check signs of partial derivatives and those other statements given at the end of the two-period model section for all combinations of chosen parameter values that satisfy the above seven conditions. Signs of the partial derivatives are found as follows. Say we are looking at the sign of $\frac{\partial Y}{\partial x} \approx \frac{Y(x+\varepsilon,\theta)-Y(x,\theta)}{\varepsilon}$, where $\theta$ contains all the other parameters except $x$ and $\varepsilon$ is a small positive number. To do this numerically we simply first compute $Y(x,\theta)$. Secondly, we compute $Y(x+\varepsilon,\theta)$, and finally we subtract the first from the second to get a value that has the same sign as the above partial derivative.

[1] $e^2/b^2$ indicates the degree of product differentiation ranging from zero when the goods are independent to one when the goods are perfect substitutes. For more on this issue see Singh and Vives (1984).

All the points used in our numerical analysis are shown in Table A1. Note that not all of $7^{10}$ permutations are relevant. Only those points were checked that satisfied the seven conditions shown above. Therefore, any combination of parameters that, for example, has *e*>*b* (i.e, import demand function has larger cross-price effect parameter than own-price effect parameter) or fails to satisfy the government's first period second-order conditions is outside the relevant range.

In Chapter V we econometrically estimate parameter values for the multi-period model that is used in our empirical analysis later on. Although the empirical multi-period model differs somewhat from the two-period model, those econometric estimates from Chapter V were used as basis for a one set of possible parameter values in the numerical analysis. The other parameter values were then picked on both sides of these values. For all those parameter values the signs of partial derivatives as well as other results were as expected. That is, we could not find a counterexample.

*Table A1. Parameter Values Used in the Numerical Analysis.*

| a | b | e | $\bar{\tau}$ | η | c | δ |
|---|---|---|---|---|---|---|
| 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.8 |
| 0.1 | 0.2 | 0.1 | 0.1 | 0.05 | 0.1 | 0.83 |
| 0.5 | 0.6 | 0.5 | 0.5 | 0.309* | 1 | 0.85 |
| 1.465* | 1.117* | 0.816* | 1 | 1 | 5 | 0.87 |
| 5 | 5 | 4.5 | 5 | 5 | 10 | 0.9 |
| 10 | 10 | 9.5 | 10 | 7 | 30 | 0.93 |
| 20 | 20 | 19 | 20 | 10 | 50 | 0.95 |
| 30 | 30 | 29 | 30 | 20 | 70 | 0.96 |
| 50 | 50 | 49 | 50 | 25 | 90 | 0.99 |
| 100 | 99 | 90 | 100 | 30 | 150 | 1 |

* Values derived from the econometric estimates of Chapter V.

## Appendix B. Data Used in the Dynamic Game Model of International Wheat Trade.

This appendix provides the data used in the construction of our dynamic game model of international wheat trade. The first four columns in Table B1 are the data used in Chapter V to estimate Moroccan import demand equations. The last two columns provide the marginal cost data used to solve for the model's base solution in Chapter VI. The data are monthly time series data from July 1992 through May 1996 for EU and U.S. wheat.

*Table B1. Monthly Wheat Exports From EU and U.S. to Morocco and Corresponding Monthly Prices Paid by Morocco and Marginal Costs for Exporting Firms.*

| | Trade flows | | Prices paid by Morocco | | Marginal costs for exporting firms | |
|---|---|---|---|---|---|---|
| | U.S. export | EC export | U.S. price | EC price | U.S. marginal costs | EU marginal costs |
| Month | metric tons | metric tons | US$/ton | US$/ton | US$/ton | US$/ton |
| Jul-92 | 0 | 143401 | 155.50 | 139.50 | 138.51 | 221.58 |
| Aug-92 | 76472 | 169248 | 119.11 | 139.50 | 133.36 | 217.91 |
| Sep-92 | 83103 | 106973 | 124.77 | 130.75 | 139.05 | 228.48 |
| Oct-92 | 78213 | 217961 | 128.43 | 133.75 | 141.25 | 233.89 |
| Nov-92 | 174060 | 129539 | 133.66 | 142.25 | 137.12 | 226.69 |
| Dec-92 | 60846 | 77689 | 124.20 | 148.00 | 143.05 | 236.42 |
| Jan-93 | 179940 | 39561 | 130.05 | 163.00 | 146.10 | 239.52 |
| Feb-93 | 246859 | 30419 | 134.46 | 166.00 | 148.56 | 239.28 |
| Mar-93 | 264777 | 17737 | 133.75 | 158.75 | 140.99 | 236.14 |
| Apr-93 | 274410 | 9515 | 129.36 | 156.75 | 136.58 | 245.55 |
| May-93 | 118634 | 0 | 119.83 | 144.75 | 130.93 | 249.26 |
| Jun-93 | 133974 | 0 | 108.32 | 130.25 | 119.94 | 237.26 |
| Jul-93 | 54857 | 151396 | 110.00 | 115.00 | 119.91 | 155.29 |
| Aug-93 | 142462 | 197469 | 103.19 | 109.75 | 120.48 | 152.39 |
| Sep-93 | 211939 | 62297 | 98.25 | 102.00 | 124.57 | 164.57 |
| Oct-93 | 95725 | 122849 | 110.87 | 109.50 | 129.23 | 172.53 |
| Nov-93 | 168562 | 55081 | 108.84 | 115.50 | 137.85 | 173.83 |
| Dec-93 | 165688 | 0 | 102.25 | 126.50 | 145.93 | 178.29 |
| Jan-94 | 117437 | 119376 | 115.46 | 126.25 | 145.20 | 200.69 |
| Feb-94 | 144041 | 157064 | 100.85 | 122.75 | 137.46 | 199.19 |
| Mar-94 | 62238 | 79870 | 94.89 | 121.50 | 133.78 | 202.82 |
| Apr-94 | 0 | 101632 | 152.00 | 99.25 | 133.05 | 202.90 |

*Table B1. continued.*

| | Trade flows | | Prices paid by Morocco | | Marginal costs for exporting firms | |
|---|---|---|---|---|---|---|
| | U.S. export | EC export | U.S. price | EC price | U.S. marginal costs | EU marginal costs |
| Month | metric tons | metric tons | US$/ton | US$/ton | US$/ton | US$/ton |
| May-94 | 24048 | 97549 | 153.00 | 105.50 | 131.48 | 212.28 |
| Jun-94 | 24807 | 0 | 152.00 | 112.50 | 131.54 | 214.51 |
| Jul-94 | 54833 | 0 | 143.00 | 110.88 | 122.86 | 180.35 |
| Aug-94 | 0 | 0 | 151.50 | 111.50 | 131.68 | 180.80 |
| Sep-94 | 0 | 0 | 167.00 | 147.63 | 144.68 | 194.61 |
| Oct-94 | 29499 | 31694 | 152.23 | 162.63 | 155.86 | 206.88 |
| Nov-94 | 0 | 0 | #N/A | 161.10 | 154.76 | 207.19 |
| Dec-94 | 0 | 6342 | #N/A | 161.92 | 154.39 | 206.94 |
| Jan-95 | 0 | 25945 | #N/A | 160.42 | 151.45 | 213.81 |
| Feb-95 | 0 | 152268 | #N/A | 158.13 | 149.76 | 182.14 |
| Mar-95 | 45913 | 166964 | 164.52 | 143.80 | 152.00 | 190.62 |
| Apr-95 | 0 | 191819 | 171.50 | 133.56 | 151.27 | 196.85 |
| May-95 | 12804 | 208806 | 155.61 | 138.95 | 158.61 | 195.74 |
| Jun-95 | 25416 | 217840 | 160.36 | 170.69 | 162.77 | 201.11 |
| Jul-95 | 0 | 108718 | #N/A | 191.75 | 173.80 | 180.15 |
| Aug-95 | 31494 | 65523 | 186.31 | 200.50 | 177.06 | 172.13 |
| Sep-95 | 52483 | 163648 | 198.31 | 206.50 | 184.24 | 178.73 |
| Oct-95 | 57610 | 65817 | 219.50 | 213.50 | 192.43 | 187.38 |
| Nov-95 | 56175 | 72259 | 220.50 | 219.00 | 195.00 | 193.73 |
| Dec-95 | 96831 | 102903 | 228.50 | 234.88 | 198.31 | 191.89 |
| Jan-96 | 59747 | 197923 | 223.50 | 223.90 | 194.87 | 193.75 |
| Feb-96 | 85876 | 25000 | 224.50 | 232.50 | 197.09 | 189.46 |
| Mar-96 | 92119 | 17391 | 220.00 | 225.88 | 197.42 | 189.84 |
| Apr-96 | 28619 | 100990 | 263.00 | 245.00 | 209.55 | 192.60 |
| May-96 | 0 | 29 | 250.50 | 268.58 | 224.98 | 195.09 |

## Appendix C. Simulation Model Code for the Dynamic Game Model of International Wheat Trade.

This appendix present the GAMS code for the base solution used in Chapter VI.

```
$OFFSYMXREF OFFSYMLIST
$INLINECOM { }

$ONTEXT
    GAMS CODE FOR THE EMPIRICAL MULTIPERIOD INTERNATIONAL
    WHEAT TRADE MODEL WITH SWITCHING COSTS
$OFFTEXT

SETS
    i      Exporters /US,EU/
    j      Time period /1*21/
    v(j)   Time period /2*21/ ;

ALIAS(r,j) ;

{
***************************************************************************
    Import demand function estimates, opportunity costs of public funds, the dis-
    count factor, and initial export volumes
***************************************************************************
}

SCALARS
    d      Discount factor                              /0.99/
    e      Cross-price effect on imports                /0.81646/ ;

PARAMETERS
    b(i)   Own-price effect on imports                  /US 1.3274, EU 0.90633/
    a(i)   Intercept of the demand function             /US 1.6388, EU 1.2916/
    M0(i)  Initial export volume                        /US 0.88598, EU 0.87118/
    n(i)   Marginal switching cost                      /US 0.35373, EU 0.26385/
    z(i)   Marginal opportunity cost of gov funds       /US 1.332, EU 1.332/
```

```
{
***********************************************************************
      Parameters for the exporter i's equation (4.47) in period j
***********************************************************************
}
      K0(i,j), K1(i,j), K2(i,j), K3(i,j), K4(i,j)
{
***********************************************************************
      Parameters for the exporter i's equation (4.48) in period j
***********************************************************************
}
      D0(i,j), D1(i,j), D2(i,j), D3(i,j), D4(i,j)
{
***********************************************************************
      Parameters for the exporter i's equation (4.51) in period j
***********************************************************************
}
      H0(i,j), H1(i,j), H2(i,j)
{
***********************************************************************
      Parameters for the exporter i's equation (4.52) in period j
***********************************************************************
}
      E0(i,j), E1(i,j), E2(i,j)
{
***********************************************************************
      Parameters for the exporter i's equation (4.53) in period j
***********************************************************************
}
      G0(i,j), G1(i,j), G2(i,j)
{
***********************************************************************
      Parameters for the exporter i's equation (4.54) in period j
***********************************************************************
}
      A0(i,j), A1(i,j), A2(i,j), A3(i,j), A4(i,j), A5(i,j)
{
***********************************************************************
      Parameters for the exporter i's equation (4.55) in period j
***********************************************************************
}
      B0(i,j), B1(i,j), B2(i,j), B3(i,j), B4(i,j), B5(i,j) ;
{
***********************************************************************
      Marginal cost for firm i in the period j
***********************************************************************
}
```

TABLE C(j,i) Marginal cost (100 dollars per ton)

| | US | EU |
|---|---|---|
| 1 | 1.3 | 1.9 |
| 2 | 1.3 | 1.9 |
| 3 | 1.3 | 1.9 |
| 4 | 1.3 | 1.9 |
| 5 | 1.3 | 1.9 |
| 6 | 1.3 | 1.9 |
| 7 | 1.3 | 1.9 |
| 8 | 1.3 | 1.9 |
| 9 | 1.3 | 1.9 |
| 10 | 1.3 | 1.9 |
| 11 | 1.3 | 1.9 |
| 12 | 1.3 | 1.9 |
| 13 | 1.3 | 1.9 |
| 14 | 1.3 | 1.9 |
| 15 | 1.3 | 1.9 |
| 16 | 1.3 | 1.9 |
| 17 | 1.3 | 1.9 |
| 18 | 1.3 | 1.9 |
| 19 | 1.3 | 1.9 |
| 20 | 1.3 | 1.9 |
| 21 | 1.3 | 1.9 |

;

```
{
************************************************************************
        Parameters for the final time period T
************************************************************************
}
```

{To solve values of the parameters for equations (4.47)-(4.55) we need to start from the final period T. First we solve the Ks for equation (4.38). In the final period firms choose their prices to maximize final-period profits. The intersection point of firms' best-response functions gives the final period prices as functions of the same period export subsidies and previous period export volumes. This is equation (4.38) where}

```
K0(i,j)$(ORD(j) EQ CARD(j)) =  (2*b(i++1)*a(i) + e*a(i++1) + 2*b(i)*b(i++1)*
                               C(j,i) + b(i++1)*e*C(j,i++1))/(4*b(i)*b(i++1) -
                               SQR(e)) ;

K1(i,j)$(ORD(j) EQ CARD(j)) =  -2*b(i)*b(i++1)/(4*b(i)*b(i++1) - SQR(e)) ;

K2(i,j)$(ORD(j) EQ CARD(j)) =  -e*b(i++1)/(4*b(i)*b(i++1) - SQR(e)) ;
```

```
K3(i,j)$(ORD(j) EQ CARD(j)) =  (2*b(i)*b(i++1)-SQR(e))*n(i)/(4*b(i)*b(i++1) -
                               SQR(e)) ;

K4(i,j)$(ORD(j) EQ CARD(j)) =  n(i++1)*K2(i,j) ;
```

{By substituting equation (4.38) and the same equation for firm k into estimated import demand functions yields equation (4.39) where}

```
D0(i,j)$(ORD(j) EQ CARD(j)) =  a(i) - b(i)*K0(i,j) + e*K0(i++1,j) ;

D1(i,j)$(ORD(j) EQ CARD(j)) =  - b(i)*K1(i,j) + e*K2(i++1,j) ;

D2(i,j)$(ORD(j) EQ CARD(j)) =  b(i)*K2(i,j) ;

D3(i,j)$(ORD(j) EQ CARD(j)) =  n(i)*D1(i,j) ;

D4(i,j)$(ORD(j) EQ CARD(j)) =  n(i++1)*D2(i,j) ;
```

{In the final period governments choose their export subsidies (taxes if negative) to maximize final-period export revenues less export subsidy expenditures. The intersection point of governments' best-response functions gives the final period subsidies as functions of previous period export volumes. This is equation (4.40) where}

```
H0(i,j)$(ORD(j) EQ CARD(j)) =  - ((1 - z(i))*D0(i,j) + D1(i,j)*K0(i,j) + D0(i,j)*
                               K1(i,j))/(2*D1(i,j)*(1 - z(i) + K1(i,j))) + ((1 - z(i))*
                               D2(i,j) + D2(i,j)*K1(i,j) + D1(i,j)*K2(i,j))*
                               (-((1 - z(i))*D0(i,j) + D1(i,j)*K0(i,j) + D0(i,j)*
                               K1(i,j))*((1 - z(i++1))*D2(i++1,j) + D2(i++1,j)*
                               K1(i++1,j) + D1(i++1,j)*K2(i++1,j)) + (2*D1(i,j)*
                               (1 - z(i) + K1(i,j)))*((1 - z(i++1))*D0(i++1,j) +
                               D1(i++1,j)*K0(i++1,j) + D0(i++1,j)*K1(i++1,j)))/
                               (2*D1(i,j)*(1 - z(i) + K1(i,j))*(4*D1(i,j)*
                               D1(i++1,j)*(1 - z(i) + K1(i,j))*(1 - z(i++1) +
                               K1(i++1,j)) - ((1 - z(i))*D2(i,j) + D2(i,j)*
                               K1(i,j) + D1(i,j)*K2(i,j))*((1 - z(i++1))*
                               D2(i++1,j) + D2(i++1,j)*K1(i++1,j) + D1(i++1,j)*
                               K2(i++1,j)))) ;

H1(i,j)$(ORD(j) EQ CARD(j)) =  - ((1 - z(i))*D3(i,j) + D3(i,j)*K1(i,j) + D1(i,j)*
                               K3(i,j))/(2*D1(i,j)*(1 - z(i) + K1(i,j))) + ((1 - z(i))*
                               D2(i,j) + D2(i,j)*K1(i,j) + D1(i,j)*K2(i,j))*
                               (-((1 - z(i))*D3(i,j) + D3(i,j)*K1(i,j) + D1(i,j)*
                               K3(i,j))*((1 - z(i++1))*D2(i++1,j) + D2(i++1,j)*
                               K1(i++1,j) + D1(i++1,j)*K2(i++1,j)) + (2*D1(i,j)*
```

```
                                    (1 - z(i) + K1(i,j)))*((1 - z(i++1))*D4(i++1,j) +
                                    D4(i++1,j)*K1(i++1,j) + D1(i++1,j)*K4(i++1,j)))/
                                    (2*D1(i,j)*(1 - z(i) + K1(i,j))*(4*D1(i,j)*D1(i++1,j)*
                                    (1 - z(i) + K1(i,j))*(1 - z(i++1) + K1(i++1,j)) -
                                    ((1 - z(i))*D2(i,j) + D2(i,j)*K1(i,j) + D1(i,j)*K2(i,j))*
                                    ((1 - z(i++1))*D2(i++1,j) + D2(i++1,j)*
                                    K1(i++1,j) + D1(i++1,j)*K2(i++1,j)))) ;

H2(i,j)$(ORD(j) EQ CARD(j)) =       - ((1 - z(i))*D4(i,j) + D4(i,j)*K1(i,j) + D1(i,j)*
                                    K4(i,j))/(2*D1(i,j)*(1 - z(i) + K1(i,j))) + ((1 - z(i))*
                                    D2(i,j) + D2(i,j)*K1(i,j) + D1(i,j)*K2(i,j))*
                                    (-((1 - z(i))*D4(i,j) + D4(i,j)*K1(i,j) + D1(i,j)*
                                    K4(i,j))*((1 - z(i++1))*D2(i++1,j) + D2(i++1,j)*
                                    K1(i++1,j) + D1(i++1,j)*K2(i++1,j)) + (2*D1(i,j)*
                                    (1 - z(i) + K1(i,j)))*((1 - z(i++1))*D3(i++1,j) +
                                    D3(i++1,j)*K1(i++1,j) + D1(i++1,j)*K3(i++1,j)))/
                                    (2*D1(i,j)*(1 - z(i) + K1(i,j))*(4*D1(i,j)*D1(i++1,j)*
                                    (1 - z(i) + K1(i,j))*(1 - z(i++1) + K1(i++1,j)) -
                                    ((1 - z(i))*D2(i,j) + D2(i,j)*K1(i,j) + D1(i,j)*K2(i,j))*
                                    ((1 - z(i++1))*D2(i++1,j) + D2(i++1,j)*
                                    K1(i++1,j) + D1(i++1,j)*K2(i++1,j)))) ;


{By substituting equation (4.40) into (4.38) yields (4.41) where}

E0(i,j)$(ORD(j) EQ CARD(j)) =   K0(i,j) + K1(i,j)*H0(i,j) + K2(i,j)*H0(i++1,j) ;

E1(i,j)$(ORD(j) EQ CARD(j)) =   K1(i,j)*H1(i,j) + K2(i,j)*H2(i++1,j) + K3(i,j) ;

E2(i,j)$(ORD(j) EQ CARD(j)) =   K1(i,j)*H2(i,j) + K2(i,j)*H1(i++1,j) + K4(i,j) ;


{By substituting equation (4.40) into (4.39) yields (4.42) where}

G0(i,j)$(ORD(j) EQ CARD(j)) =   D0(i,j) + D1(i,j)*H0(i,j) + D2(i,j)*H0(i++1,j) ;

G1(i,j)$(ORD(j) EQ CARD(j)) =   D1(i,j)*H1(i,j) + D2(i,j)*H2(i++1,j) + D3(i,j) ;

G2(i,j)$(ORD(j) EQ CARD(j)) =   D1(i,j)*H2(i,j) + D2(i,j)*H1(i++1,j) + D4(i,j) ;


{By substituting equations (4.41) and (4.42) into government i's objective
function yields (4.44) where}

A0(i,j)$(ORD(j) EQ CARD(j)) =   E0(i,j)*G0(i,j) + (1 - z(i))*G0(i,j)*H0(i,j) ;
```

```
A1(i,j)$(ORD(j) EQ CARD(j)) =  E1(i,j)*G0(i,j) + E0(i,j)*G1(i,j) +
                               (1 - z(i))*(G1(i,j)*H0(i,j) + G0(i,j)*H1(i,j)) ;

A2(i,j)$(ORD(j) EQ CARD(j)) =  E0(i,j)*G2(i,j) + E2(i,j)*G0(i,j) +
                               (1 - z(i))*(G2(i,j)*H0(i,j) + G0(i,j)*H2(i,j)) ;

A3(i,j)$(ORD(j) EQ CARD(j)) =  E1(i,j)*G1(i,j) + (1 - z(i))*G1(i,j)*H1(i,j) ;

A4(i,j)$(ORD(j) EQ CARD(j)) =  E2(i,j)*G2(i,j) + (1 - z(i))*G2(i,j)*H2(i,j) ;

A5(i,j)$(ORD(j) EQ CARD(j)) =  E2(i,j)*G1(i,j) + E1(i,j)*G2(i,j) +
                               (1 - z(i))*(G2(i,j)*H1(i,j) + G1(i,j)*H2(i,j)) ;


{And by substituting equations (4.41) and (4.42) into firm i's objective function yields
(4.43) where}

B0(i,j)$(ORD(j) EQ CARD(j)) =  (E0(i,j) + H0(i,j) - C(j,i))*G0(i,j) ;

B1(i,j)$(ORD(j) EQ CARD(j)) =  (E0(i,j) + H0(i,j) - C(j,i))*G1(i,j) +
                               (E1(i,j) + H1(i,j))*G0(i,j) ;

B2(i,j)$(ORD(j) EQ CARD(j)) =  (E0(i,j) + H0(i,j) - C(j,i))*G2(i,j) +
                               (E2(i,j) + H2(i,j))*G0(i,j) ;

B3(i,j)$(ORD(j) EQ CARD(j)) =  (E1(i,j) + H1(i,j))*G1(i,j) ;

B4(i,j)$(ORD(j) EQ CARD(j)) =  (E2(i,j) + H2(i,j))*G2(i,j) ;

B5(i,j)$(ORD(j) EQ CARD(j)) =  (E1(i,j) + H1(i,j))*G2(i,j) +
                               (E2(i,j) + H2(i,j))*G1(i,j) ;

{
***************************************************************************
      Parameters for periods 1 to T-1
***************************************************************************
}

{Now the values of the parameters in equations (4.38)-(4.44) for t=T are solved. By
backward induction this procedure can be repeated for all the remaining T-1 periods to
receive the values of different parameters As, Bs, Ds, Es, Gs, Hs, and Ks. This is done in
a LOOP that follows.
Omegas and lambdas shown below are created just to decrease the length of
equations.}
```

```
PARAMETERS
        omega(i,j)      denominator in K
        lambda0(i,j)    part of denominator in H
        lambda1(i,j)    part of denominator in H ;

LOOP(r, LOOP(j$(ORD(j) EQ (CARD(j)+1 -ORD(r))),

omega(i,j) =    1 - ((e - d*(2*b(i++1)*e*B4(i,j+1) + 2*b(i)*e*B3(i,j+1) -
                (b(i)*b(i++1) + SQR(e))*B5(i,j+1)))/
                (2*(b(i) - d*(SQR(b(i))*B3(i,j+1) - b(i)*e*B5(i,j+1) +
                SQR(e)*B4(i,j+1)))))*((e - d*(2*b(i)*e*B4(i++1,j+1) +
                2*b(i++1)*e*B3(i++1,j+1) - (b(i++1)*b(i) + SQR(e))*B5(i++1,j+1)))/
                (2*(b(i++1) - d*(SQR(b(i++1))*B3(i++1,j+1) - b(i++1)*e*
                B5(i++1,j+1) + SQR(e)*B4(i++1,j+1))))) ;

K0(i,j) =       ((b(i)*C(j,i) + (1 - d*(2*b(i)*B3(i,j+1) - e*B5(i,j+1)))*a(i) +
                d*(2*e*B4(i,j+1) - b(i)*B5(i,j+1))*a(i++1) - d*(b(i)*B1(i,j+1) -
                e*B2(i,j+1)))/(2*(b(i) - d*(SQR(b(i))*B3(i,j+1) - b(i)*e*B5(i,j+1)+
                SQR(e)*B4(i,j+1)))) + (b(i++1)*C(j,i++1) +
                (1 - d*(2*b(i++1)*B3(i++1,j+1) - e*B5(i++1,j+1)))*a(i++1) +
                d*(-b(i++1)*B5(i++1,j+1) + 2*e*B4(i++1,j+1))*a(i) -
                d*(b(i++1)*B1(i++1,j+1) - e*B2(i++1,j+1)))/(2*(b(i++1) -
                d*(SQR(b(i++1))*B3(i++1,j+1) - b(i++1)*e*B5(i++1,j+1) +
                SQR(e)*B4(i++1,j+1))))*(e - d*(2*b(i++1)*e*B4(i,j+1) +
                2*b(i)*e*B3(i,j+1)-(b(i)*b(i++1) + SQR(e))*B5(i,j+1)))/(2*(b(i) -
                d*(SQR(b(i))*B3(i,j+1) - b(i)*e*B5(i,j+1) +
                SQR(e)*B4(i,j+1)))))/omega(i,j) ;

K1(i,j) =       (-b(i)/(2*(b(i) - d*(SQR(b(i))*B3(i,j+1) - b(i)*e*B5(i,j+1) +
                SQR(e)*B4(i,j+1)))))/omega(i,j) ;

K2(i,j) =       ((-e + d*(2*b(i++1)*e*B4(i,j+1) + 2*b(i)*e*B3(i,j+1) -
                (b(i)*b(i++1) + SQR(e))*B5(i,j+1)))*b(i++1)/(4*(b(i) -
                d*(SQR(b(i))*B3(i,j+1) - b(i)*e*B5(i,j+1) + SQR(e)*
                B4(i,j+1)))*(b(i++1) - d*(SQR(b(i++1))*B3(i++1,j+1) -
                b(i++1)*e*B5(i++1,j+1) + SQR(e)*B4(i++1,j+1)))))/omega(i,j) ;

K3(i,j) =       (1 + K1(i,j))*n(i) ;

K4(i,j) =       K2(i,j)*n(i++1) ;

D0(i,j) =       a(i) - b(i)*K0(i,j) + e*K0(i++1,j) ;

D1(i,j) =       -b(i)*K1(i,j) + e*K2(i++1,j) ;

D2(i,j) =       e*K1(i++1,j) - b(i)*K2(i,j) ;
```

```
D3(i,j) =         b(i)*(n(i) - K3(i,j)) + e*K4(i++1,j) ;

D4(i,j) =         -b(i)*K4(i,j) + e*(K3(i++1,j) - n(i++1)) ;

lambda0(i,j) =    2*(d*(A3(i,j+1)*SQR(D1(i,j)) + A5(i,j+1)*D1(i,j)*D2(i++1,j) +
                  A4(i,j+1)*SQR(D2(i++1,j))) + (1 - z(i) + K1(i,j))*D1(i,j)) ;

lambda1(i,j) =    (d*(2*A3(i,j+1)*D1(i,j)*D2(i,j) + A5(i,j+1)*(D1(i,j)*D1(i++1,j) +
                  D2(i,j)*D2(i++1,j)) + 2*A4(i,j+1)*D1(i++1,j)*D2(i++1,j)) +
                  D1(i,j)*K2(i,j) + (1 - z(i) + K1(i,j))*D2(i,j))/lambda0(i,j) ;

H0(i,j) =         (1/(1 - lambda1(i,j)*lambda1(i++1,j)))*(-(d*(A1(i,j+1)*D1(i,j) +
                  2*A3(i,j+1)*D0(i,j)*D1(i,j) + A5(i,j+1)*(D1(i,j)*D0(i++1,j) +
                  D0(i,j)*D2(i++1,j)) + A2(i,j+1)*D2(i++1,j) + 2*A4(i,j+1)*D0(i++1,j)*
                  D2(i++1,j)) + D1(i,j)*K0(i,j) + (1 - z(i) + K1(i,j))*D0(i,j))/
                  lambda0(i,j) + lambda1(i,j)*(d*(A2(i++1,j+1)*D2(i,j) +
                  2*A4(i++1,j+1)*D0(i,j)*D2(i,j) + A5(i++1,j+1)*D2(i,j)*D0(i++1,j) +
                  A1(i++1,j+1)*D1(i++1,j) + A5(i++1,j+1)*D0(i,j)*D1(i++1,j) +
                  2*A3(i++1,j+1)*D0(i++1,j)*D1(i++1,j)) + D1(i++1,j)*K0(i++1,j) +
                  (1 - z(i++1) + K1(i++1,j))*D0(i++1,j))/lambda0(i++1,j)) ;

H1(i,j) =         (1/(1 - lambda1(i,j)*lambda1(i++1,j)))*(-(d*(2*A3(i,j+1)*D1(i,j)*
                  D3(i,j) + A5(i,j+1)*(D3(i,j)*D2(i++1,j) + D1(i,j)*D4(i++1,j)) +
                  2*A4(i,j+1)*D2(i++1,j)*D4(i++1,j)) + (1 - z(i) + K1(i,j))*D3(i,j) +
                  D1(i,j)*K3(i,j))/lambda0(i,j) + lambda1(i,j)*(d*(2*A4(i++1,j+1)*
                  D2(i,j)*D3(i,j) + A5(i++1,j+1)* (D3(i,j)*D1(i++1,j) + D2(i,j)*
                  D4(i++1,j)) + 2*A3(i++1,j+1)*D1(i++1,j)*D4(i++1,j)) +
                  (1 - z(i++1) + K1(i++1,j))*D4(i++1,j) + D1(i++1,j)*K4(i++1,j))/
                  lambda0(i++1,j)) ;

H2(i,j) =         (1/(1 - lambda1(i,j)*lambda1(i++1,j)))*
                  (-(d*(2*A3(i,j+1)*D1(i,j)*D4(i,j) + A5(i,j+1)*(D4(i,j)*D2(i++1,j) +
                  D1(i,j)*D3(i++1,j)) + 2*A4(i,j+1)*D2(i++1,j)*D3(i++1,j)) +
                  (1 - z(i) + K1(i,j))*D4(i,j) + D1(i,j)*K4(i,j))/lambda0(i,j) +
                  lambda1(i,j)*(d*(2*A4(i++1,j+1)*D2(i,j)*D4(i,j) + A5(i++1,j+1)*
                  (D4(i,j)*D1(i++1,j) + D2(i,j)*D3(i++1,j)) +
                  2*A3(i++1,j+1)*D1(i++1,j)*D3(i++1,j)) +
                  (1 - z(i++1) + K1(i++1,j))*D3(i++1,j) + D1(i++1,j)*K3(i++1,j))/
                  lambda0(i++1,j)) ;

E0(i,j) =         K0(i,j) + K1(i,j)*H0(i,j) + K2(i,j)*H0(i++1,j) ;

E1(i,j) =         K1(i,j)*H1(i,j) + K2(i,j)*H2(i++1,j) + K3(i,j) ;

E2(i,j) =         K1(i,j)*H2(i,j) + K2(i,j)*H1(i++1,j) + K4(i,j) ;
```

```
G0(i,j) =     D0(i,j) + D1(i,j)*H0(i,j) + D2(i,j)*H0(i++1,j) ;

G1(i,j) =     D1(i,j)*H1(i,j) + D2(i,j)*H2(i++1,j) + D3(i,j) ;

G2(i,j) =     D1(i,j)*H2(i,j) + D2(i,j)*H1(i++1,j) + D4(i,j) ;

A0(i,j) =     E0(i,j)*G0(i,j) + (1 - z(i))*G0(i,j)*H0(i,j) + d*(A0(i,j+1) +
              A1(i,j+1)*G0(i,j) + A2(i,j+1)*G0(i++1,j) + A3(i,j+1)*SQR(G0(i,j)) +
              A4(i,j+1)*SQR(G0(i++1,j)) + A5(i,j+1)*G0(i,j)*G0(i++1,j)) ;

A1(i,j) =     E1(i,j)*G0(i,j) + E0(i,j)*G1(i,j) + (1 - z(i))*(G1(i,j)*H0(i,j) +
              G0(i,j)*H1(i,j)) + d*(A1(i,j+1)*G1(i,j)+A2(i,j+1)*G2(i++1,j) +
              2*A3(i,j+1)*G0(i,j)*G1(i,j) + 2*A4(i,j+1)*G0(i++1,j)*G2(i++1,j) +
              A5(i,j+1)*(G1(i,j)*G0(i++1,j) + G0(i,j)*G2(i++1,j))) ;

A2(i,j) =     E0(i,j)*G2(i,j) + E2(i,j)*G0(i,j) + (1 - z(i))*(G2(i,j)*H0(i,j) +
              G0(i,j)*H2(i,j)) + d*(A1(i,j+1)*G2(i,j)+A2(i,j+1)*G1(i++1,j) +
              2*A3(i,j+1)*G0(i,j)*G2(i,j) + 2*A4(i,j+1)*G0(i++1,j)*G1(i++1,j) +
              A5(i,j+1)*(G2(i,j)*G0(i++1,j) + G0(i,j)*G1(i++1,j))) ;

A3(i,j) =     E1(i,j)*G1(i,j) + (1 - z(i))*G1(i,j)*H1(i,j) + d*(A3(i,j+1)*
              SQR(G1(i,j)) + A4(i,j+1)*SQR(G2(i++1,j)) +
              A5(i,j+1)*G1(i,j)*G2(i++1,j)) ;

A4(i,j) =     E2(i,j)*G2(i,j) + (1 - z(i))*G2(i,j)*H2(i,j) + d*(A3(i,j+1)*
              SQR(G2(i,j)) + A4(i,j+1)*SQR(G1(i++1,j)) +
              A5(i,j+1)*G2(i,j)*G1(i++1,j)) ;

A5(i,j) =     E2(i,j)*G1(i,j) + E1(i,j)*G2(i,j) + (1 - z(i))*(G2(i,j)*H1(i,j) +
              G1(i,j)*H2(i,j)) + d*(2*A3(i,j+1)*G1(i,j)*G2(i,j) + 2*A4(i,j+1)*
              G1(i++1,j)*G2(i++1,j) + A5(i,j+1)*(G1(i,j)*G1(i++1,j) +
              G2(i,j)*G2(i++1,j))) ;

B0(i,j) =     (E0(i,j) + H0(i,j) - C(j,i))*G0(i,j) + d*(B0(i,j+1) + B1(i,j+1)*
              G0(i,j) + B2(i,j+1)*G0(i++1,j) + B3(i,j+1)*SQR(G0(i,j)) +
              B4(i,j+1)*SQR(G0(i++1,j)) + B5(i,j+1)*G0(i,j)*G0(i++1,j)) ;

B1(i,j) =     (E0(i,j) + H0(i,j) - C(j,i))*G1(i,j) + (E1(i,j) + H1(i,j))*G0(i,j)+
              d*(B1(i,j+1)*G1(i,j) + B2(i,j+1)*G2(i++1,j) + 2*B3(i,j+1)*G0(i,j)*
              G1(i,j) + 2*B4(i,j+1)*G0(i++1,j)*G2(i++1,j) + B5(i,j+1)*(G1(i,j)*
              G0(i++1,j) + G0(i,j)*G2(i++1,j))) ;

B2(i,j) =     (E0(i,j) + H0(i,j) - C(j,i))*G2(i,j) + (E2(i,j) + H2(i,j))*G0(i,j)+
              d*(B1(i,j+1)*G2(i,j) + B2(i,j+1)*G1(i++1,j) + 2*B3(i,j+1)*G0(i,j)*
              G2(i,j) + 2*B4(i,j+1)*G0(i++1,j)*G1(i++1,j) + B5(i,j+1)*(G2(i,j)*
              G0(i++1,j) + G0(i,j)*G1(i++1,j))) ;
```

```
B3(i,j) =      (E1(i,j) + H1(i,j))*G1(i,j) + d*(B3(i,j+1)*SQR(G1(i,j)) +
               B4(i,j+1)*SQR(G2(i++1,j)) + B5(i,j+1)*G1(i,j)*G2(i++1,j)) ;

B4(i,j) =      (E2(i,j) + H2(i,j))*G2(i,j) + d*(B3(i,j+1)*SQR(G2(i,j)) +
               B4(i,j+1)*SQR(G1(i++1,j)) + B5(i,j+1)*G2(i,j)*G1(i++1,j)) ;

B5(i,j) =      (E1(i,j) + H1(i,j))*G2(i,j) + (E2(i,j) + H2(i,j))*G1(i,j) +
               d*(2*B3(i,j+1)*G1(i,j)*G2(i,j) + 2*B4(i,j+1)*G1(i++1,j)*
               G2(i++1,j) + B5(i,j+1)*(G1(i,j)*G1(i++1,j) + G2(i,j)*G2(i++1,j))) ;
);) ;


PARAMETERS
*Quantities
       M(i,j)    Period j exports from country i to importing country

*Price
       P(i,j)    Period j importer border price for good exported from i

*Subsidies
       S(i,j)    Period j export subsidy offered by government i

*Payoff measures
       W(i,j)    Present and discounted future welfare for exporting country i at period j
       Prof(i,j) Present and discounted future profits for exporting firm i at period j ;
{
*********************************************************************
       Markov Perfect Equilibrium
*********************************************************************
}

{After we have solved parameters for all the time periods, we can get the equilibrium
solutions by forward induction. Starting from the first period the equilibrium values for
export subsidies, prices, export volumes, firms' profits, and governments' welfares can
be easily received because they are functions of already solved parameters and initial
values of export volumes.}

{
*********************************************************************
       Equilibrium Export Volumes for Period 1
*********************************************************************
}
       M(i,"1") = G0(i,"1") + G1(i,"1")*M0(i) + G2(i,"1")*M0(i++1) ;
```

```
{
***********************************************************************
        Equilibrium Prices for Period 1
***********************************************************************
}
        P(i,"1") = E0(i,"1") + E1(i,"1")*M0(i) + E2(i,"1")*M0(i++1) ;
{
***********************************************************************
        Equilibrium Export Subsidies for Period 1
***********************************************************************
}
        S(i,"1") = H0(i,"1") + H1(i,"1")*M0(i) + H2(i,"1")*M0(i++1) ;
{
***********************************************************************
        Equilibrium Government Welfare for Period 1
***********************************************************************
}
        W(i,"1") =    A0(i,"1") + A1(i,"1")*M0(i) + A2(i,"1")*M0(i++1) +
                      A3(i,"1")*SQR(M0(i)) + A4(i,"1")*SQR(M0(i++1)) +
                      A5(i,"1")*M0(i)*M0(i++1) ;
{
***********************************************************************
        Equilibrium Profits for Period 1
***********************************************************************
}
        Prof(i,"1") = B0(i,"1") + B1(i,"1")*M0(i) + B2(i,"1")*M0(i++1) +
                      B3(i,"1")*SQR(M0(i)) + B4(i,"1")*SQR(M0(i++1)) +
                      B5(i,"1")*M0(i)*M0(i++1) ;
{By forward induction this same procedure is then repeated to all of the remaining time
periods to achieve the Markov Perfect Equilibrium of this dynamic international wheat
trade model. The LOOP below does this.}

{
***********************************************************************
        Equilibrium Values for Periods 2 to T
***********************************************************************
}

LOOP(v,

M(i,v) =    G0(i,v) + G1(i,v)*M(i,v-1) + G2(i,v)*M(i++1,v-1) ;

P(i,v) =    E0(i,v) + E1(i,v)*M(i,v-1) + E2(i,v)*M(i++1,v-1) ;

S(i,v) =    H0(i,v) + H1(i,v)*M(i,v-1) + H2(i,v)*M(i++1,v-1) ;
```

```
W(i,v) =    A0(i,v) + A1(i,v)*M(i,v-1) + A2(i,v)*M(i++1,v-1) +
            A3(i,v)*SQR(M(i,v-1)) + A4(i,v)*SQR(M(i++1,v-1)) +
            A5(i,v)*M(i,v-1)*M(i++1,v-1) ;

Prof(i,v) = B0(i,v) + B1(i,v)*M(i,v-1) + B2(i,v)*M(i++1,v-1) +
            B3(i,v)*SQR(M(i,v-1)) + B4(i,v)*SQR(M(i++1,v-1)) +
            B5(i,v)*M(i,v-1)*M(i++1,v-1) ;
) ;

PARAMETERS  EXPORTS(i,j)
            PRICE(i,j)
            SUBSIDY(i,j)
            WELFARE(i,j)
            PROFITS(i,j) ;

EXPORTS(i,j) = 100000*M(i,j) ;
PRICE(i,j) = 100*P(i,j) ;
SUBSIDY(i,j) = 100*S(i,j) ;
WELFARE(i,j) = 10000000*W(i,j) ;
PROFITS(i,j) = 10000000*Prof(i,j) ;

FILE SOL /'BaseSoln.sol'/ ;
PUT SOL ;
SOL.PC = 5 ;
SOL.PW =255 ;
PUT '';
PUT 'US Exports' ; PUT 'EU Exports' ;
PUT 'US Price' ; PUT 'EU Price' ;
PUT 'US Subsidy' ; PUT 'EU Subsidy' ;
PUT 'US Welfare' ; PUT 'EU Welfare' ;
PUT 'US Profits' ; PUT 'EU Profits' ;
PUT /;
LOOP(j,
        PUT j.TL ;
        LOOP(i,
            PUT EXPORTS(i,j) ;) ;
        LOOP(i,
            PUT PRICE(i,j) ;) ;
        LOOP(i,
            PUT SUBSIDY(i,j) ;) ;
        LOOP(i,
            PUT WELFARE(i,j) ;) ;
        LOOP(i,
            PUT PROFITS(i,j) ;) ;
        PUT /;
) ;
```

## Appendix D. Comparison of an Ex Ante and an Ex Post Game.

A simplified one-period (two stage) model without switching costs is used here to illustrate differences between equilibrium outcomes of an ex ante game and an ex post game. The ex ante game assumes that governments set subsidy levels before exporting firms set prices in the importing country. In the ex post game the order of moves by firms and governments is assumed to be reversed. That is, governments decide on subsidy levels only after firms have set their prices.

It is assumed that products are differentiated and that import demand functions are linear and symmetric. In addition, the firms are assumed to have constant marginal costs, equal to $c$. Notation is the same as that provided in Chapter IV unless otherwise stated.

The next section states the equilibrium results of the ex ante game. Then equilibrium results for the ex post game are shown. Finally, the last section shows how results differ when timing in decisions is reversed.

### Ex Ante Game

Firms choose prices at the second stage of the game to maximize profits, taking the subsidy levels chosen by the governments as fixed. Firm $i$'s profits are

$$\pi^i = \left(P^i + S^i - c\right)M^i . \tag{A.1}$$

The import demand function, $M^i$, for this single period framework without switching costs is written as $M^i = a - bP^i + eP^k$, where $i$, $k$ = U.S., EU, $i \neq k$, $a$>0, and $b$>$e$>0. In the first stage, each government maximizes domestic welfare by choosing its export subsidy given expected firm behavior. Domestic welfare is written as

$$W^i = \left(P^i + S^i\right)M^i - \mu S^i M^i . \tag{A.2}$$

The procedure to solve for the subgame perfect equilibrium of this game is the same as in Chapter IV. Therefore, only the equilibrium results for export subsidies, prices, export volumes, profits and welfare are presented below.

$$S^i = S^k = \frac{-\left[(\mu-1)\left(4b^2-e^2\right)+e^2\right]a+\left[e\left(2b^2-e^2\right)+\mu(b-e)\left(4b^2-e^2\right)\right]c}{\left[\mu(2b-e)\left(4b^2-be-2e^2\right)-2(b-e)\left(2b^2-e^2\right)\right]} \tag{A.3}$$

(A.4) $$P^i = P^k = \frac{2\left[(\mu-1)\left(2b^2-e^2\right)+zb^2\right]a + b(\mu-1)\left(2b^2-e^2\right)c}{\left[\mu(2b-e)\left(4b^2-be-2e^2\right)-2(b-e)\left(2b^2-e^2\right)\right]}$$

(A.5) $$M^i = M^k = \frac{b\mu\left(2b^2-e^2\right)a + b(\mu-1)(b-e)\left(2b^2-e^2\right)c}{\left[\mu(2b-e)\left(4b^2-be-2e^2\right)-2(b-e)\left(2b^2-e^2\right)\right]}$$

(A.6) $$\pi^i = \pi^k = \frac{b\left[\mu\left(2b^2-e^2\right)a + (\mu-1)(b-e)\left(2b^2-e^2\right)c\right]^2}{\left[\mu(2b-e)\left(4b^2-be-2e^2\right)-2(b-e)\left(2b^2-e^2\right)\right]^2} = \frac{\left(M^2\right)^2}{b}$$

(A.7) $$W^i = W^k = \frac{\left[(\mu-1)\left(2b^2-e^2\right)+2b^2\mu\right]\left(M^i\right)^2}{b\left(2b^2-e^2\right)}$$

## Ex Post Game[2]

The model is again a two-stage game. In stage 1 exporting firms $i$ and $k$ set prices $p^i$ and $p^k$, respectively. Then in stage 2 governments set per unit subsidies taking firms prices as predetermined (and therefore fixed). Note that these prices, $p^i$ and $p^k$, are total prices received by exporting firms. Thus, prices paid by an importing country ("net prices") are now written as $p^i$-$S^i$ and $p^k$-$S^k$ instead of $P^i$ and $P^k$ (as in the ex ante game). The import demand for country $i$'s exports is therefore written as

(A.8) $$M^i = a - b\left(p^i - S^i\right) + e\left(p^k - S^k\right).$$

and government $i$'s welfare maximization problem in the second stage of the game is

(A.9) $$\underset{S^i}{Max} \quad W^i = \left(p^i - \mu S^i\right)\left(a - b\left(p^i - S^i\right) + e\left(p^k - S^k\right)\right).$$

[2] For more complete discussion on ex post games see, for example, Neary (1991) and Gruenspecht (1988).

Taking prices as given, the government $i$'s welfare-maximization problem yields the following solution for $S^i$.

$$\text{(A.10)} \quad S^i\left(p^i, p^k\right) = \frac{-a}{(2b-e)} + \frac{\left(2b^2 - e^2\right)\mu + 2b^2}{\mu\left(4b^2 - e^2\right)} p^i - \frac{(\mu - 1)be}{\mu\left(4b^2 - e^2\right)} p^k$$

Note a problem with the special case of $\mu = 1$. If additional welfare cost of public funds is zero, that is $\mu = 1$, then from (A.10) we see that $dS^i/dp^i = 1$. This means that country $i$'s government would exactly offset stage 1 price increases by its exporting firm with higher subsidies, on a dollar for dollar basis. Recognizing this the firm would choose to set an infinite price in the first stage, relying on an infinitely large government subsidy to restore its competitive position. In the remainder of this appendix it is assumed that $\mu > 1$.

In the first stage of the game each exporting firm chooses its own price to maximize profits, anticipating the effects of its choice of price on governments subsidies in the second stage. Thus, the exporting firm $i$'s problem is

$$\text{(A.11)} \qquad \underset{p^i}{Max} \quad \pi^i = \left(p^i - c\right)M^i .$$

The resulting equilibrium values are

$$\text{(A.12)} \quad S^i = S^k = \frac{\left[(2-\mu)\left(2b^2 - e^2\right) + 2b^2\right]}{(\mu - 1)(2b - e)\left(4b^2 - be - 2e^2\right)} a + \frac{\left(2b^2 - e^2\right)\left(b + (b - e)\mu\right)}{\left[\mu(2b - e)\left(4b^2 - be - 2e^2\right)\right]} c,$$

$$\text{(A.13)} \qquad p^i = p^k = \frac{\mu(2b + e)}{(\mu - 1)\left(4b^2 - be - 2e^2\right)} a + \frac{\left(2b^2 - e^2\right)}{\left(4b^2 - be - 2e^2\right)} c,$$

$$\text{(A.14)} \quad M^i = M^k = \frac{b\left(2b^2 - e^2\right)}{(2b - e)\left(4b^2 - be - 2e^2\right)} a - \frac{(\mu - 1)(b - e)}{\mu(2b - e)\left(4b^2 - be - 2e^2\right)} c,$$

$$\text{(A.15)} \quad \pi^i = \pi^k = \frac{b(2b + e)\left(2b^2 - e^2\right)\left[\mu a - (\mu - 1)(b - e)c\right]^2}{\mu(\mu - 1)(2b - e)\left(4b^2 - be - 2e^2\right)^2} = \frac{\mu\left(4b^2 - e^2\right)\left(M^i\right)^2}{b(\mu - 1)\left(2b^2 - e^2\right)},$$

$$\text{(A.16)} \qquad W^i = W^k = \frac{\mu\left(M^i\right)^2}{b}.$$

Subtracting equation (A.12) from (A.13) yields equilibrium prices paid by the importing country:

$$\text{(A.17)} \quad P^i = P^k = p^i - S^i = p^{ik} - S^k = \frac{2\mu\left(3b^2 - e^2\right)a + b(\mu - 1)\left(2b^2 - e^2\right)c}{\mu(2b - e)\left(4b^2 - be - 2e^2\right)}.$$

## Comparison of Ex Ante and Ex Post Equilibrium Solutions

In an ex post game the firms are first-movers. Therefore, they have more market power than in an ex ante game. This implies that firms are able to extract larger subsidies from their governments and charge higher prices for their wheat in the importing country than in an ex ante model. These results can be seen by subtracting the ex ante equilibrium subsidy from the ex post equilibrium subsidy and the ex ante equilibrium price from the ex post equilibrium price.

$$S^{\text{ex post}} - S^{\text{ex ante}} = \left[\frac{b\left[\mu a - (\mu - 1)(b - e)c\right]}{\mu(\mu - 1)(2b - e)\left(4b^2 - be - 2e^2\right)}\right] \cdot \left[\frac{\left[2\left(2b^2 - e^2\right)^2 - \mu\left(2b^2 - e^2\right)\left(4b^2 - be - 2e^2\right) + 2b\mu^2(2b - e)\left(4b^2 - be - 2e^2\right)\right]}{\left[\mu(2b - e)\left(4b^2 - be - 2e^2\right) - 2(b - e)\left(2b^2 - e^2\right)\right]}\right]$$

and

$$P^{\text{ex post}} - P^{\text{ex ante}} = \frac{2b\left(2b^2 - e^2\right)^2\left[\mu a - (\mu - 1)(b - e)c\right]}{\mu(2b - e)\left(4b^2 - be - 2e^2\right)\left[\mu(2b - e)\left(4b^2 - be - 2e^2\right) - 2(b - e)\left(2b^2 - e^2\right)\right]}$$

Recall that $a>0$, $b>e>0$ and $\mu>1$. The two equations above are always positive when $a - (b-e)c \geq 0$. Condition $a - (b-e)c \geq 0$ just means that exporting firms are exporting nonnegative amounts of wheat.[3]

The larger prices paid by the importing country imply that smaller exports of wheat take place in the ex post model than in the ex ante model. Subtracting equation (A.5) from (A.14) yields

[3] It can be shown that a condition for exporting firm $i$ to export nonnegative amounts of wheat is $a + eP^k \geq bc$. Since $bc - eP^k$ gets larger the lower is $P^k$, it is sufficient to look at the case where $P^k = c$, which is the lowest price exporter $k$ can charge. Then we get the condition $a \geq (b - e)c$ for nonnegative export volumes.

$$M^{\text{ex post}} - M^{\text{ex ante}} = \frac{-2b(b-e)(2b^2-e^2)^2[\mu a - (\mu-1)(b-e)c]}{\mu(2b-e)(4b^2-be-2e^2)[\mu(2b-e)(4b^2-be-2e^2)-2(b-e)(2b^2-e^2)]} < 0.$$

A comparison of equations (A.6) and (A.15) verifies that, due to increased firm level market power, firm profits are higher in the ex post game than in the ex ante game.

$$\pi^{\text{ex post}} - \pi^{\text{ex ante}} = \frac{b(2b^2-e^2)^2[\mu a-(\mu-1)(b-e)c]^2\left[4(b-e)^2(2b+e)(2b^2-e^2)^2\right.}{[\mu(\mu-1)(2b-e)(4b^2-be-2e^2)}$$

$$\frac{\left.+2b^2\mu^2(2b-e)(4b^2-be-2e^2)^2-\mu(2b-e)(2b^2-e^2)(4b^2-be-2e^2)(4b^2-3be-2e^2)\right]}{\cdot[\mu(2b-e)(4b^2-be-2e^2)-2(b-e)(2b^2-e^2)]^2]} > 0$$

Finally, government's welfare in the ex post game is always smaller than the level of welfare in the ex ante game as can be seen below.

$$W^{\text{ex post}} - W^{\text{ex ante}} = \frac{\mu(2b^2-e^2)}{b(2b^2-e^2)}(M^{\text{ex post}})^2 - \left[\frac{\mu(2b^2-e^2)}{b(2b^2-e^2)} + \frac{2b^2(\mu-1)+e^2}{b(2b^2-e^2)}\right](M^{\text{ex ante}})^2 < 0.$$

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