Trade Games:
Noncooperative Strategies in the International Wheat Market

David Vanzetti
B.Ec. (Hons) W. Aust., and M.Sc. (Agric. Econs) Reading, U.K.

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School of Economics
La Trobe University
Bundoora, Victoria, 3083
Australia
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Summary

International commodity markets have most commonly been analysed with the use of perfectly competitive models, ignoring the effects of government intervention combined with market power. Such models are unable to account for retaliation and other strategic effects that have recently been observed in wheat and other agricultural markets.

In this thesis, a framework is developed for analysing strategic interactions in agricultural trade. Policymakers set domestic prices to optimise weighted welfare functions, where the weights reflect the relative influence of consumers, producers and taxpayers. These weights are estimated from observed domestic prices in each region.

Non-cooperative, game-theoretic equilibria are utilised to determine the outcome of trade wars under various scenarios.

Cournot-Nash, Stackelberg and conjectural variations solutions are obtained in a static framework. The analysis is then extended to include lags in production and decision making, and the strategic and dynamic elements of the policymaker's problem are examined in a dynamic difference game. Prices are set in each region to optimise a quadratic objective function, subject to linear intertemporal constraints. A dynamic programming approach, using Riccati equations, is developed to solve for the single controller problem. An iterative procedure is then applied to take account of the interdependence of all countries' policies.

To incorporate storage in the deterministic model, multi-period quadratic programming is used to find the optimum tariffs and stock levels simultaneously. This approach allows the restriction that stocks must be non-negative.

The analysis is applied to a model of the international wheat market. The results indicate that strategic behaviour can significantly influence optimal trade policy, and hence prices, trade flows and the distribution of welfare.

Statement of Authorship

Except where reference is made in the text of this thesis, this thesis contains no material published elsewhere or extracted in whole or part from a thesis presented by me for another degree or diploma.

No other person's work has been used without due acknowledgment in the main text of the thesis.

This thesis has not been submitted for the award of any other degree or diploma in any other tertiary institution.

Various supervisors have provided direction and guidance during my candidature. A number of conference papers, discussion papers and articles in refereed journals have been co-authored with my main supervisor, John Kennedy. These works are acknowledged and referenced in the main text of the thesis. In accordance with regulation C 6(b), published work is included in an Appendix to the thesis.

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Chapter 1

Trade Games: Introduction and Overview

1.1 Introduction

A major feature of agricultural trade in the 1980s is substantial government intervention. The major exporters use export subsidies to reduce stocks and to improve or maintain their share of the market. This has led to substantial falls in world prices. Such policies are far removed from the perfectly competitive environment which economists have commonly favoured when analysing international trade, and which leads to free trade as the preferred, Pareto optimal policy. Why is there such a gap between observed reality and the theoretically preferred policies? Three possible reasons are the structure of many agricultural markets, the distributional preferences of governments, and the inability of free traders to enforce collective action.

In many, although by no means all, international trade models, the effect of market power is ignored or treated as exogenous. Yet, for many commodities, there exist relatively few traders on one or both sides of the market. Also of importance is the number of potential entrants, in this case the number of producers. In the wheat trade, five countries supply the bulk of all exports, and there are few producing countries with the potential to export significant amounts. Government action can be seen as bringing producers or consumers together to enable them to exercise market power. Where more than one country holds some power, the potential for conflict over its use arises. When one country exercises such power, retaliation can be expected.

Trade policy involves more than setting trade taxes in such a way as to maximise monopoly rents. Governments intervene to achieve other objectives, such as price stability and income redistribution. Government policies in the European Community [EC], the United States and Japan are notable examples of policies which significantly influence world trade. While the influence of government has long been recognised, it is only recently that attempts have been made to identify the determinants of government action. One approach to endogenising government policy highlights domestic political factors, such as the relative bargaining strength of various pressure groups. Weights can be attached to the welfare attributed to various groups in society. These weights may be estimated using a revealed preference methodology. The weights can be used for comparative purposes, both across countries and through time, but more importantly, have implications for the response by one country to policy changes in another.

Free trade can be seen as a public good, exhibiting elements of non-excludability and non-rivalry. Free trade depends on cooperation, as each country with the ability to influence world prices has an incentive to 'free ride' by setting optimal trade taxes. With a large number of traders, it is difficult for any one country to punish another for defection. If it is in no individual country's interest to reduce trade barriers unilaterally, then in the absence of multilateral agreements, Pareto-inferior outcomes are unlikely. Without cooperation to make the benefits of free trade excludable, the resulting outcomes may deviate considerably from what any nation wants, even though the benefits of collective action are clear. This problem is often referred to as the 'Tragedy of the Commons', in reference to overgrazing of public pastures.

With imperfectly competitive market structures, the interventionist tendencies of governments and a public good problem, a number of countries have the incentive to impose some form of trade barrier. Such policies affect the world price, and hence other countries. Thus, each country's welfare depends not only on its own actions, but on those of other countries as well. Any policy change which influences other countries' welfare is likely to draw a response. In these situations, strategic behaviour is evident. A strategy is a complete description of the player's decision rule, a plan of action contingent on unknown events. In trade, these events comprise the actions or reactions of other traders. Strategic policymaking involves giving consideration to the likely decisions of other policymakers. Game theory can be used to analyse strategic situations of this nature.

Games can be formulated in many different ways, depending upon the information available to the players, the number of players and the influence of each, the degree of cooperation, the objectives and the instruments used to achieve objectives. In games applied to trade, each country usually has an incentive to cooperate, but there is also an incentive to defect, so long as this does not lead to defection by other countries. Asymmetry in size and an increase in the number of players are two factors leading to defection rather than cooperation. If two or more players have sufficient incentive to defect, trade wars may occur. The outcome of trade wars in the absence of cooperation is the subject of this thesis.

1.2 The Agricultural Crisis

Before considering which game characterises the international wheat trade, a brief review of the current state of the market is necessary.

At the start of 1988 the international grain trade was in crisis. Prices had been falling throughout the 1980s and were as low as they had been for three decades. Stocks reached record levels. The cost of farm income support was unprecedented, yet incomes and land values remained at politically unacceptable levels, particularly in the USA. As a result, debt levels and foreclosures had risen beyond acceptable limits. The short and medium-term outlook for grain producers appeared bleak.

A North American drought and, to a lesser extent, continued use of export subsidies, resulted in a significant reduction in stocks in 1988. This led to a recovery in prices. While the short-term outlook for prices is promising, the price resurgence hides a number of fundamental problems in the world grain markets. The problems relate to government assistance measures to producers[1]. The respite now being enjoyed by farmers provides an opportunity to redress some of these problems.

Policies designed to ease domestic farm income problems have led to a worsening of the situation. Farm income support measures have resulted in excess production, increasing stocks and continued low prices. The burden of adjustment has increasingly been transferred to the international market as large trading countries or blocs have insulated their domestic markets. Productivity improvements, particularly in China and India, and slow economic and population growth have contributed to the very limited expansion in grain demand for both human consumption and stock feed.

In considering how the grain trade fits into the simplistic framework outlined earlier, it is necessary to regard a number of protective measures as equivalent to the tariff. Policies take a variety of forms, including tariffs, export subsidies and taxes, quotas, deficiency payments, variable levies, acreage controls and other measures. Each can be evaluated in terms of its effect on the domestic prices. It is assumed that the differential between domestic and world prices can be treated as if it were a tariff, or a subsidy. This differential captures the net effect of assistance to the sector.

1.3 Objectives

The general objective of this thesis is to derive and apply a framework for analysing non-cooperative strategic behaviour (including retaliation) in international trade. Application of the framework provides answers to the following questions:

- Does strategic behaviour exist?
- Can such behaviour be described, explained and predicted?
- What are the effects on trade flows, prices and welfare?
- How are the welfare gains and losses distributed?
- Are there winners from trade wars?

[1]Other causes of the agricultural crisis are macroeconomic in origin. Miller (1987) notes that large budget deficits in some developed countries, and large international debts in developing countries have contributed to the problem. (p. 906)

- Is free trade the optimal policy for an individual country?
- What is the optimal policy, and what are the determinants?
- What is the scope for cooperation with other countries?
- Will exporters use subsidies as a short-run strategic measure to drive out competition, and so benefit in the long run?

In achieving the general objective, a number of specific objectives are met. First, the static Cournot-Nash and Stackelberg trade war solutions are derived. The Cournot-Nash equilibrium is a standard noncooperative game-theoretic solution, and shows the prices, trade flows and welfare consistent with each country imposing its optimal tariffs. Assuming no cooperation exists, the effect of retaliation can be assessed. Optimal policies with and without retaliation can be compared. The cost of a trade war can be ascertained.

The Cournot-Nash solution is based on the assumption that traders do not expect rivals to retaliate, although they can be observed doing so. All traders make their decisions simultaneously. However, if one country can commit itself to an action before the others, a Stackelberg analysis applies. The followers choose their best policy given the leader's policy, which can be observed. The leader, in setting its policy, takes the followers' expected actions into account. This provides a different outcome to the Cournot-Nash solution.

In spite of allowing for strategic effects, many observed policies cannot be explained in terms of efficiency objectives. Policymakers are not optimising an unweighted welfare function, but are setting policies to redistribute resources to certain groups in society. Policies reflect the relative bargaining strengths of various pressure groups. These influences can be captured by attaching weights to the welfare function of each country. The weights reflect the preferences of the policymaker concerning the distribution of resources to various groups in society, and can be estimated using a revealed preference methodology. They have implications for the response of one country to policy changes in another.

In the Cournot-Nash model, rivals are assumed by each trader not to retaliate. This assumption is relaxed in a conjectural variations model. Expected responses are taken into account when setting policy. The introduction of non-zero expectations of retaliation changes the outcome of a trade war.

If rivals respond only after some time has elapsed, or if there are production lags or other adjustment costs, a dynamic model is most appropriate for analysing policy. The strategic and dynamic effects can be captured in a dynamic game model. The path to equilibrium can be studied in such games. The effects of discounting, different time horizons, supply side lag structures and changes in the level of autonomous growth in the parameters can be assessed.

Finally, in a dynamic model, it is sensible to include storage. The ability to store can have an effect on the optimal tariff levels, even in the deterministic model developed in this study.

In calculating the outcomes of trade war, it is assumed that players set import tariffs or export taxes/subsidies to optimise a welfare function, given linear demand and supply schedules. Different algorithms are derived to meet various specific objectives. The framework is applied to the international wheat market, which is disaggregated into twenty one different regions. The wheat market is chosen because of its importance and market structure. The techniques developed can be applied to many commodity markets, and are especially suited to those in which two or more large countries can significantly influence the world price.

The model presented here is theoretical. Application of the model to the international wheat market should be seen as illustrative of the usefulness of the approach. Although the model captures the essence of the strategic trade policy problem, it is not sufficiently refined to be used for detailed policy analysis. For this reason, the model has not been validated. The refinements required to make the models useful for policy analysis are described in the final chapter.

1.4 Outline

The outline of this thesis is as follows. An introduction to some game-theoretic concepts is given in the next chapter. This includes definitions of relevant gaming terms, and a description of some basic game structures. Some common noncooperative and cooperative equilibria are then described. The relationship between statics and dynamics is discussed in the penultimate section of the chapter, and finally, some of the limitations of game theory are outlined.

In Chapter 3, the applicability of game theory for analysing the world wheat market is ascertained. This depends on market power, which stems from the structure of the world wheat market, and the extent to which the market power held by some countries is exercised, which relates to the degree of government involvement. Market structure depends upon the distribution of production, consumption and stockholding between various countries. Government involvement determines how potential market power is used, and therefore a summary of the policies of the major wheat exporters and importers is presented. It is these policies which have contributed to the problems noted earlier. Empirical evidence of the effects of some countries' policies on other countries is presented. To conclude the chapter, a brief history of retaliation and trade disputes is presented. This includes a discussion of export subsidies, which cause much concern. From evidence presented in the chapter, it is apparent that government intervention is substantial, that market power exists and that there is considerable conflict in the international wheat market.

Previous attempts to model strategic behaviour in agricultural trade are examined in Chapter 4. Retaliation from a trade-theoretic viewpoint is assessed first. Static models, including those using weighted welfare functions, are then noted. The various attempts to use conjectural variation models to explain trade flows are described. Finally, dynamic models are reviewed. A review of the literature relating to the strategic use of storage is postponed until Chapter 8.

The derivation and application of the static models is described in Chapter 5. First, the assumptions and characteristics common to all versions of the model are discussed. The static Cournot-Nash and Stackelberg solutions are then derived, as is a procedure for estimating welfare weights for both two and three groups. In interpreting the weights, care needs to be taken to ensure they are stable and representative, and not the unintended consequence of previous policies or the result of political failure. The technique is then applied to a twenty one sector model of the international wheat trade. Throughout this study, it is assumed that policymakers set policies so as to maximise a welfare function.

An exception to this is presented at the end of Chapter 5. It is assumed that exporters set subsidies so as to attain a given market share. This serves to illustrate the need to carefully formulate objectives, as the market share solution is quite different from the welfare maximising solution.

The role of positive expectations of retaliation is examined in Chapter 6, in which the conjectural variations game-theoretic solution is applied to the same market as in Chapter 5. Conjectures are estimated, and are used to show how they would affect the response to a 20 per cent depreciation of the US dollar.

Policymakers in agricultural trade are concerned not only that changes in their policy induce changes in other countries' policies, but also about the time profile of the effects of policies. The strategic and dynamic elements of the problem are jointly considered in a dynamic game framework, presented in Chapter 7. A dynamic programming framework, utilising Riccati equations, is used to solve the single controller problem of finding an optimal set of tariffs over time. An iterative optimal control procedure is used to account for the interdependence of all countries' policies. As in the static version of the model, the welfare functions are weighted according to the policymakers' revealed preferences. The weights significantly influence the outcome of a trade war.

The solution technique used in Chapter 7 requires the intertemporal constraints to be equalities. This precludes having storage in the model, as stocks cannot be negative. In Chapter 8, a dynamic model with storage is presented. Optimal tariff and stock levels are found simultaneously. Quadratic programming is used to accommodate inequalities.

The final chapter contains a summary and review of the major results. The results are then related to the objectives, and the implications are reviewed. The contributions of this study are noted, and finally, some refinements and extensions which would improve the model are discussed.

Chapter 2

Game-Theoretic Considerations

2.1 Introduction

This chapter provides a brief introduction to game theory. The concepts discussed here are utilised in later chapters. The suitability of the technique for analysing trade disputes is established.

2.2 Some Definitions

McMillan (1986 p. 1) describes game theory as follows:

> The theory of games provides a set of mathematical techniques for analysing situations in which each agent's utility depends not only on his own actions but also on the actions of others; and all of the agents take these interdependencies into account when deciding their actions.

Consider a monopolist determining optimum output. This situation is not game-theoretic, because profits do not depend on the actions of rivals. Now consider an oligopolistic determining its profit-maximising output. As profits depend on how other firms respond, this is a game-theoretic problem. The oligopolist's problem is quite different, McMillan elaborates, from the traditional optimisation problems, in which only one, albeit multifaceted, objective function is maximised. No one agent can control all the variables. Clearly then, games can take many forms. To describe these forms, a little vocabulary is needed. Greater detail, and indeed, a comprehensive survey of games, can be found in Schotter and Schwödiauer (1980).

Games can be classified according to the amount of information available. Where the only information given is the outcomes associated with each strategy, games are known as *strategic* or *normal*. By contrast, games in *extensive form* specify the dynamic nature of the problem. This includes the order of play, the information available to the players when they make their decisions, and the evolution of the game. At the opposite end of the information spectrum, the *characteristic function form* of the game refers to situations where the payoff of only one player is specified.

Games can also be described as *cooperative* or *noncooperative*, depending on whether the players can make binding and enforceable agreements with each other, and act in concert. Cooperative games sometimes involve *sidepayments*, paid by one player to a coalition member to preserve the arrangement.

The gains or losses accruing to each player are specified in a *payoff* function. In economics, this commonly refers to a utility, welfare or profit function. In a game, each player attempts to optimise the payoff subject to the strategies of others. Depending on the sum of the players' payoff functions, games may be *zero-sum, constant-sum* or *non-constant-sum*. The first is clearly a subset of the second. In non-constant-sum games, actions by one player may benefit, rather than harm, other players. Such games have elements of both conflict and cooperation. Many trade games are of this nature[1]. Gains from trade may benefit all players, but there is conflict over how the gains are distributed.

The actions, or *strategies* of players must be defined for every situation. For games in extensive form, the sequence of actions must be specified. In strategic games, actions

[1]Not all trade games are non-constant-sum. Exceptions include games involving market shares, in which the total market is shared in different ways. An example of a market shares game is presented in Chapter 5.

		Country B F	Country B T
Country A	F	3,3	1,4
	T	4,1	2,2

Table 2.1: Prisoners' Dilemma

take place simultaneously, or at least without any agent knowing the decisions of the other players.

2.3 Basic Game Structures

The relevance of game theory to international trade can be illustrated in the following examples. Consider a two-country two-commodity model, with each country importing one good and exporting the other, and where the traders are of equal size, in terms of their potential impact on the terms of trade. Each player can set its tariff at zero (free trade) or at the optimum level. With the ability to influence the world price, the optimal tariff is positive for each country. Small countries without the ability to alter the world price have an optimal tariff of zero. There are thus four pairs of outcomes, of which free trade is globally optimal, and both players lose if each sets a tariff.

2.3.1 Prisoners' dilemma

Consider the matrix shown in Table 2.1. Country A's payoff is the first of each pair shown in the table. For example, 4,1 indicates that if Country A sets a tariffs but Country B does not, A receives a payoff of 4 in contrast to 1 for B.

The free trade solution is 3,3. However, Country A player can improve on this if it sets a tariff and B does not respond. On the other hand, if B sets a tariff initially, A's best response is also a positive tariff. By responding with a tariff, A moves from a payoff of 1 to 2. This involves a gain for A of 1, and a loss for B of 2. Free trade leads to a global maximum, but each country has an incentive to impose a tariff, as long as its rival maintains the free trade strategy.

A's preferred ranking of outcomes can be represented as

$$T_A F_B > F_A F_B > T_A T_B > F_A T_B$$

where T and F refer to a tariff and the free trade policy respectively, and the subscripts A and B denote the countries setting the policy. Player A prefers the outcome $T_A F_B$, in which it sets a tariff and B maintains a free trade policy. The least preferred outcome for A is $F_A T_B$, in which the policy settings are reversed. A game with this ranking of references is known as a *prisoners' dilemma*[2]. With each country assuming that its rival may retaliate, both are worse off than if both cooperate. A diagrammatic representation of each players preference ordering for this and other games is presented in Figure 2.1.

This is a powerful result. In the absence of communication (or trust), both parties choose policies which lead them both to be worse off then under a free trade regime. Yet, each is not prepared to reduce tariffs unilaterally, in case the other does not cooperate, leaving the free trader in the worst possible position. The depression of the 1930s can be regarded as an example of the prisoners' dilemma game.

2.3.2 Deadlock

The prisoners' dilemma game is applicable when the players are of approximately equal size. Consider a situation in which one player can influence the terms of trade to a far greater extent than the other. The payoff matrix is shown in Table 2.2.

This variation of the prisoners' dilemma game is known as *deadlock* (Conybeare 1985,

[2]This is often referred to as a prisoner's dilemma, but as both players face the dilemma, the plural seems more appropriate.

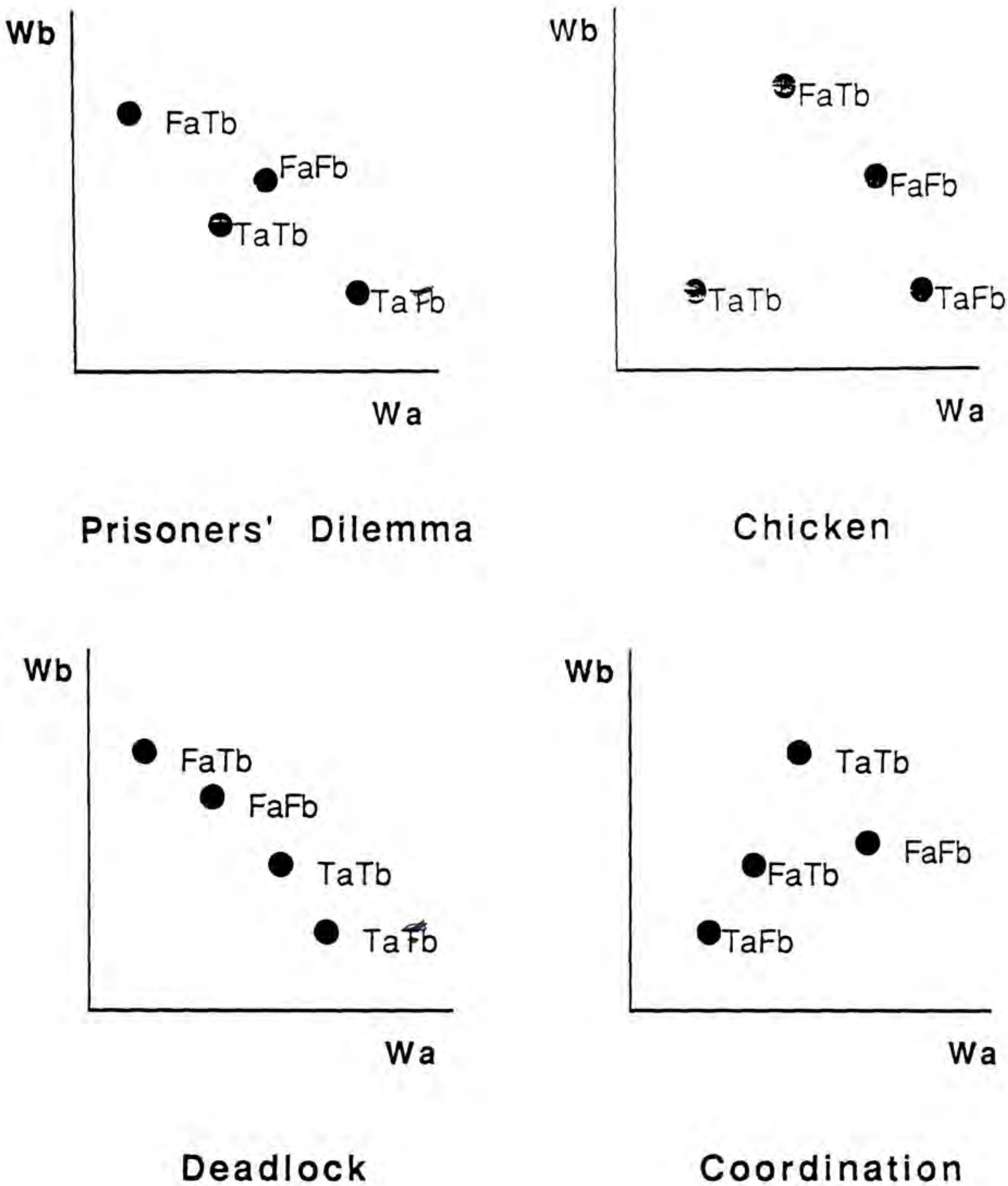


Figure 2.1: Basic Game Structures

		Country B: F	Country B: T
Country A	F	10,5	8,6
	T	12,1	11,2

Table 2.2: Deadlock

		Country B	
		F	T
Country A	F	4,3	2,2
	T	1,1	3,4

Table 2.3: Coordination Game

p. 35) because the dominant strategy is unconditional noncooperation. A's preferred ranking of outcomes are:

$$T_A F_B > T_A T_B > F_A F_B > F_A T_B$$

The free trade solution is 10,5. However, Country A player can improve on this if it sets a tariff, regardless of whether its rival responds. The tariff solution dominates. Free trade leads to a global maximum, but country A prefers to impose a tariff. Given Country A's position, B's best policy is also a positive tariff. This outcome is known as the 'Johnson case' in the trade literature, after its exposition by Johnson in 1954.

Riezman (1982) analyses tariffs in this framework. He concludes that in reality *'free trade may be difficult to obtain when countries behave strategically'* (p. 591). The tariff-ridden strategy dominates a free trade strategy if one player benefits from a trade war or if the gains from eliminating tariffs are unequally distributed (p. 592). Riezman suggests that this result helps explain the failure of multilateral trade negotiations to lead to free trade.

2.3.3 The coordination game

The coordination game is central to trade theory. It refers to a situation where *'each player imposes costs or benefits on the other contingent upon the other's policy'*. (Snidal 1985, p. 931-32) This is a problem of collective action, in that the appropriate coordinated action may favour one player over the other. The matrix in Table 3.3 illustrates:

Whereas the games of prisoners' dilemma and deadlock described here had unique, stable, albeit inefficient, solutions, the coordination game has multiple stable equilibria. Once at equilibrium, neither player has an incentive to move. These equilibria are Cournot-Nash. A Cournot-Nash equilibrium need not be unique. Hence, $F_A F_B$ and $T_A T_B$ are Pareto outcomes, but the distribution of gains is unequal. A's preference ordering is:

$$F_A F_B > T_A T_B > F_A T_B > T_A F_B$$

Examples of coordination problems abound in economics and in international relations. Trade according to comparative advantage is one example. Each country must choose the commodities in which to specialise in production. No advantage is gained if both countries specialise in the one good. More striking examples are the need for standardised communications. Similar railway gauges between adjoining states is another example. Demand management policies also require coordination at the international level.

2.3.4 Chicken

A game in which mutual defection is disastrous is known as *chicken*[3]. The concept of mutually assured destruction, on which the NATO nuclear policy appears to be based, is an example of chicken. Cooperation is enforced by the threat of severe losses if mutual defection occurs. In trade, small countries are often in this situation. They are better off being exploited by a large country as opposed to imposing a tariff which is harmful to themselves. The preference ordering for small country A is:

$$T_A F_B > F_A F_B > F_A T_B > T_A T_B$$

[3]I have never seen any reference to the origin of this name, but have always thought the term referred to the following spectacle. Two foolhardy players drive their cars at one another along the white line on a quiet road. The player who swerves (cooperates) at the last moment is termed a 'chicken', a colloquial expression for one who lacks courage.

Two players may have different preference orderings, and hence are playing different games. When the two traders are different in size, the large one may be playing deadlock, while the smaller is playing chicken. The small country may threaten a tariff war in the hope that this will force cooperation from the large country. However, such a policy is likely to be unsuccessful if the large trader prefers a trade war to free trade.

The simple 2x2 models presented here are sufficient to illustrate the nature of the trade problem. Obvious extensions are the number of possible actions (tariff levels), the number of countries, and repeated playing of the game over time. These factors complicate the analysis. Increasing the number of players lessens the probability of cooperative behaviour, repeated plays raise it.

The international grain trade has two characteristics which suggest the game of deadlock is most applicable. It has asymmetry in the influence of players. Small countries tend to benefit most from free trade, and large countries, which can influence the world price, are likely to benefit from trade barriers, possibly even if retaliation occurs. The second characteristic is large numbers on the import side of the market. The large numbers represent a public goods problem. If the nature of the game changes to a prisoners' dilemma, perhaps due to a change in market share or some other factor, the free rider problem prevents the solution evolving from $T_A T_B$ to $F_A F_B$, the free trade solution.

2.4 Large Numbers and Public Goods

Free trade is efficient in the sense that those disadvantaged by trade can be compensated from the gains. However, the existence of public goods implies that Pareto optimality may not be attained, because free riders are able to enjoy the benefits of free trade while protecting their domestic industries. This often involves a transfer from consumers to producers within the free riding country. As the benefits of setting a tariff are not excludable, each country tends to defect, even in a repeated game. The provision of free trade is thus a public good problem. Runge, von Witzke and Thompson (1987) maintain that the role of institutions such as GATT is to provide an assurance against free riding. Public goods can then be provided at Pareto optimal levels. This is known as the assurance problem (p. 6). Each player contributes to the public good only if there is an assurance that other players will do likewise. GATT attempts to provide such assurance through the Most Favoured Nation (MFN) clause, which outrules discrimination in trade. However, GATT has limited power, and hence provides limited assurance. As the number of players rises, each defection has less effect on the world price, and hence non-excludability and non-rivalry increase. It becomes harder for any individual player to punish any other who defects. An increase in the number of players reduces the probability of cooperation, and hence of free trade.

The nature of the game is determined by such factors as asymmetry, repeated plays, number of players and other variables such as the quality of information and the perceived payoff function the players are attempting to optimise. The solution concepts are dependent upon the type of game being played. In this work, applications involve only noncooperative games. The Cournot-Nash, Stackelberg and conjectural variations equilibria are applied empirically.

2.5 Noncooperative Solutions

2.5.1 Cournot-Nash

The Cournot-Nash equilibrium is a point at which no trader (acting unilaterally) can do better than playing its optimum (Nash) strategy, given that all other traders are playing their optimum strategies. The strategy for each player is to maximise the payoff taking as given the actions of the other players. The solution derives from Cournot's oligopoly model which is based on the behavioural assumption that each firm maximizes profits assuming that its rivals' output remains constant. Interaction between the firms ensures convergence to a point from which no firm wants to move. As the number of firms increases, the price and output levels approach the competitive levels.

The Cournot-Nash equilibrium can be represented as follows:

$$x^N \equiv (x_1^N, \ldots, x_n^N)$$

is a Nash equilibrium if, for all $i = 1, \ldots, n$,

$$u^i(x_1^N, \ldots, x_{i-1}^N, x_i^N, x_{i+1}^N, \ldots, x_n^N)$$

$$\geq u^i(x_1^N, \ldots, x_{i-1}^N, x_i, x_{i+1}^N, \ldots, x_n^N)$$

for all $x_i \in X_i$.

Assuming differentiability of the welfare function, the solution is found by solving n simultaneous first order equations:

$$\frac{\partial u^i}{\partial x_i} = 0,$$

for all $i = 1, \ldots, n$.

Without cooperation, a unique solution can be attained if there are no nonlinearities, and the objective function for each player is quadratic. These conditions are assumed throughout this work.

In Figure 2.2, the Cournot-Nash equilibrium is shown diagrammatically for two players. This diagram is from McMillan (1986). Country 1's tariff, t^1 is on the horizontal axis, and t^2 is on the vertical axis. For a given level of t^2, 1's best reply is shown by the curve R^1. This curve is downward sloping because as 2's tariff is raised, 1's best response is reduced. This is shown in the indifference curves, u^1, which represent an increase in welfare as they approach the horizontal axis. A similar set of indifference curves and reaction function exist for country 2. The reaction function passes through the maximum point of each indifference curve. The only point from which neither trader would want to move, given the others strategy, is at the intersection of R^1 and R^2. This is the Cournot-Nash equilibrium. At such a position both countries are worse off than at free trade, but from the origin welfare can be increased by setting a tariff, given one's rival does

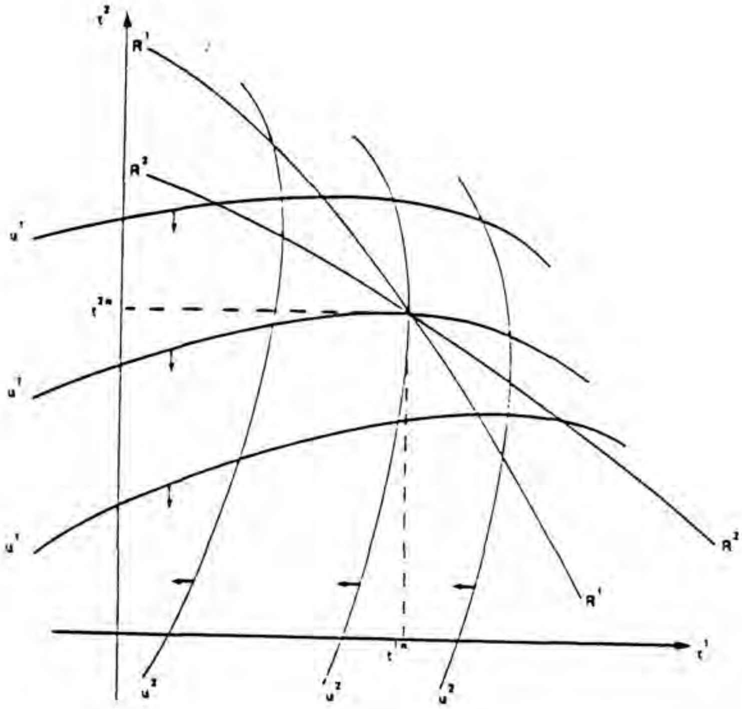


Figure 2.2: Cournot-Nash Tariff Equilibrium

not respond. Free trade is not a Nash equilibrium, at least with the indifference curves depicted here.

In the Cournot model as applied to industrial organisation, the decision variable is the quantity of output. If, instead, prices are chosen as the decision variable, one firm could capture the whole market by lowering its price. Retaliation leads to prices being forced down to the perfectly competitive level. This is the so-called Bertrand model.

This conclusion does not hold in trade models. Although tariffs and taxes are the decision variables, they impinge predominantly on the domestic markets. The world price is influenced by all domestic prices, but once determined, all countries face the one border price (with zero transport costs). Hence, in international trade, retaliation does not lead to the abolition of tariffs.

The Cournot-Nash solution is a method of assessing the impact of retaliation. While it enables an analysis of market power in a systematic fashion, it is often criticised because traders' actions are assumed to be short sighted at best, in that rivals are expected not to react, although this expectation is repeatedly falsified. McMillan (1986) maintains that it is incorrect to view traders' behaviour as naive, and this view comes from the notion that the model is dynamic (p. 12). In fact the model can be seen as static, with actions occurring only once, and need not be based on a *dynamic* adjustment process. The time path to equilibrium is not specified. If there is a unique equilibrium, and if each agent knows its rivals' strategy, it knows that they rationally choose the Cournot-Nash policy. Each agent plays its best strategy, given that its rivals are playing their best. The Cournot-Nash equilibrium may be seen as a very sophisticated, albeit static, equilibrium.

2.5.2 Stackelberg

The Stackelberg solution is based on the concept that policies are formed in two stages: first, a market leader determines its policy, and second, the followers respond by implementing their optimum policies. The leader sets the policy which maximises its interest taking account that the followers react in their best interests. The followers act in a Cournot-Nash fashion, assuming no reaction from others. (This assumption is necessary for a stable equilibrium.) There are thus $n-1$ first order conditions, one for each follower. For any given policy of the leader, the payoff can be determined by simultaneously solving the $n-1$ equations. The leader then selects the policy providing the greatest payoff.

2.5.3 Conjectural variations

The conjectural variations model is a more general version of the Cournot and Stackelberg models. In the conjectural variations model, it is assumed that responses are not known with certainty, but that each firm makes a guess (or conjecture) as to how rivals vary their output in response to a change in output by the first firm. By specifying different conjectures from -1 (perfect competition) through 0 (Cournot) to 1 (monopoly) many types of market structure can be modelled (see Nelson and McCarl (1984) for a discussion of this). The number of possible equilibria is infinite, and this is in some ways a weakness of the theory. Conversely, conjectural variations estimates can be obtained from an observed market structure.

Undoubtedly, traders do have some notion of how rivals may respond, and trade models would be improved by the inclusion of such information. Responses take time, and although formally static (like the Cournot model) McMillan maintains that the conjectural variations model contains an implicitly dynamic adjustment process, and is in fact similar to a repeated game model. However, the dynamics are not specified. For example, there is no discounting in the model. The time period involved is captured in the elasticities.

2.6 Cooperative Solutions

In discussing solutions, a brief reference must be made to cooperative solutions. They are not used in this work, although, of course, there is scope for analysing trade problems in a cooperative framework. A problem with such solutions is the possibility of multiple equilibria. To illustrate, consider three people dividing a dollar. If two agree on a fifty-fifty share, the third person may offer one of the others sixty cents, thereby obtaining forty cents rather than nothing. There is no stable solution to this problem.

The *core* is a set of outcomes such that no coalition can make all its members better off. It is Pareto optimal, as far as the players are concerned. The core may be large, with many possible solutions. An alternative concept is the *Shapley value*, which generates a unique solution. Each agent obtains a payoff equal to a weighted average of its marginal contribution to all possible coalitions. The marginal contribution is the difference between total payoff to the coalition with and without the cooperation of that agent. The Shapley value has been applied, for example, to public utility pricing (Schotter and Schwödiauer 1980 p. 491). A third concept is that of the *nucleolus*. This is akin to Rawls's concept of equity, according to Littlechild and Thompson (1977), and can be used to derive equitable cost shares. The nucleolus is a point at which the payoff to the worst-off player is at a maximum.

2.7 Statics, Dynamics and Related Matters

Static games have no links between time periods. In fact, time is not specified. *Dynamic* games involve lags which link time periods. However, the distinction between static and dynamic games is not as simple as this. As both types of games are used in the following chapters, the distinction is discussed in some detail.

2.7.1 Repeated games

Static games imply that players make their decisions simultaneously, or at least without knowing the decisions of other players. In *repeated* games or *supergames*, decisions are made in sequence. Each player knows the previous decisions of the other players. Repeated games are of interest because they break down the distinction between cooperative and noncooperative solutions. In a noncooperative static game, the solution is frequently Pareto-inferior, because each player is following a unilateral strategy. In cooperative games, ability to make sidepayments to compensate potential losers lead to a solution closer to the Pareto optimum. In a repeated game, cooperation can be forced by the possibility of retaliation. In fact, as McMillan shows (p. 15), the repeated playing of a static Nash equilibrium is a dynamic Nash equilibrium. As long as the discount rate is not too high, the threat of retaliation in the future prevents players from deviating from the Pareto strategy and adopting the static unilateral Nash strategy.

Two commonly analysed strategies involving repeated plays are 'tit for tat' and 'trigger'. The first involves cooperating initially, then doing what one's rival does. The second involves cooperation until the rival defects, and playing the noncooperative move thereafter. Tit for tat has intuitive appeal, possibly because it accommodates long periods of cooperation, and quickly punishes any defection. Although interesting, these strategies will not be considered further in the study.

2.7.2 Finite horizon

This equivalence between static and repeated games tends to break down if the time horizon is finite, as each player knows that there can be no retaliation after the last period, nor can there be any forceful threat that can be used in the second last period, and so on. Under such circumstances, cooperation is less easy to enforce.

2.7.3 Dynamic games

Repeated games are the simplest kind of dynamic games. More complex dynamic games involve lags in production or response to a policy change. These lags constitute an intertemporal link. In other words, the state variable is a function of the lagged value of the control. To illustrate with an agricultural example, production may be a lagged function of prices and other variables influenced by policy. Where such games are modelled in discrete time, they are referred to as *difference games*. These games are used later in this study.

2.7.4 Open and closed loops

In dynamic games, two types of strategy are commonly assumed. *Open loop* refers to a situation where each agent's action is a function of time alone, and is specified at the beginning of the time horizon. This yields a different solution to the *closed loop* equilibrium, where each strategy is a function of the state variable as well as time. At the beginning of the time horizon, each agent is committed to a decision rule, rather than a specific set of actions. The decision rule is the best reply given the actions of other agents.

2.8 Limitations of Game Theory

What are the disadvantages of game-theoretic analysis? These relate to the application of the theory. Brander (1986) notes that because of the range of different policies, it is difficult to determine the correspondence between the policies of different countries. It is difficult to distinguish 'tit' from 'tat' (p. 42). In providing export subsidies, is the USA responding to EC export restitutions, or is it initiating a new round of trade barriers.

A further difficulty is the multilateral nature of trade and trade negotiations. Policies aimed at one country may have consequences for others. Targeted export subsidies may lead to reductions in world prices, if the product is homogenous or the market unsegmented, resulting in reprisals from third countries.

In addition to calculating response functions, other problems in implementation of game theory include specification of the state variables, the control variables and the payoff function. These factors are subject to measurement error, and it is often difficult to assess which variables should be regarded as the appropriate instruments or targets. Objectives may also be difficult to determine. For example, do the Americans attach any weight to the effects of their policies on Canada or the USSR? How important are geopolitical concerns? The specification of the payoff function in any model to be used for policy analysis needs careful consideration.

In this chapter the basic concepts of game theory have been described. These concepts are utilised in the material presented in the following chapters.

Chapter 3

The Nature of Conflict in Agricultural Trade

It is argued in this chapter that because of the structure and nature of the international commodity markets, agricultural trade can be analysed with game-theoretic methods.

Conflict in agricultural trade arises when two necessary conditions are met. These are the existence of potential market power and government intervention. In isolation, each has little effect[1]. Conflict occurs when governments intervene either to exercise potential market power, or to influence their own domestic markets. If countries are large enough to possess market power, domestic arrangements may also effect the world price, even though this is an unintended consequence. For example, a deficiency payments scheme without production controls may lead to oversupply and a fall in world prices, increasing the cost of the scheme, and adversely affecting other exporters.

[1]Government intervention is required if there are a large number of producers within each country. If there are only a small number, such as in the aerospace industry, the individual firms may be able to exercise market power without government intervention.

3.1 Market Power

Market power is the ability of traders to influence trade flows and price. Conceptually, it is the concentration of producers, rather than exporters, that is important, as many producers have the potential to become exporters. With many individual producers and consumers, it might appear that agricultural markets are classic examples of competitive markets. Indeed, many domestic markets, for horticultural products for example, do function in a competitive fashion. Why, then, is international trade in agricultural products so different? One reason is that governments act to coordinate consumers or producers to provide them with market power that they can exercise on the international market.

In this section, the extent and nature of market power in the grain trade is examined. This is determined by national production, consumption and stock positions. These factors are described first.

3.1.1 Production

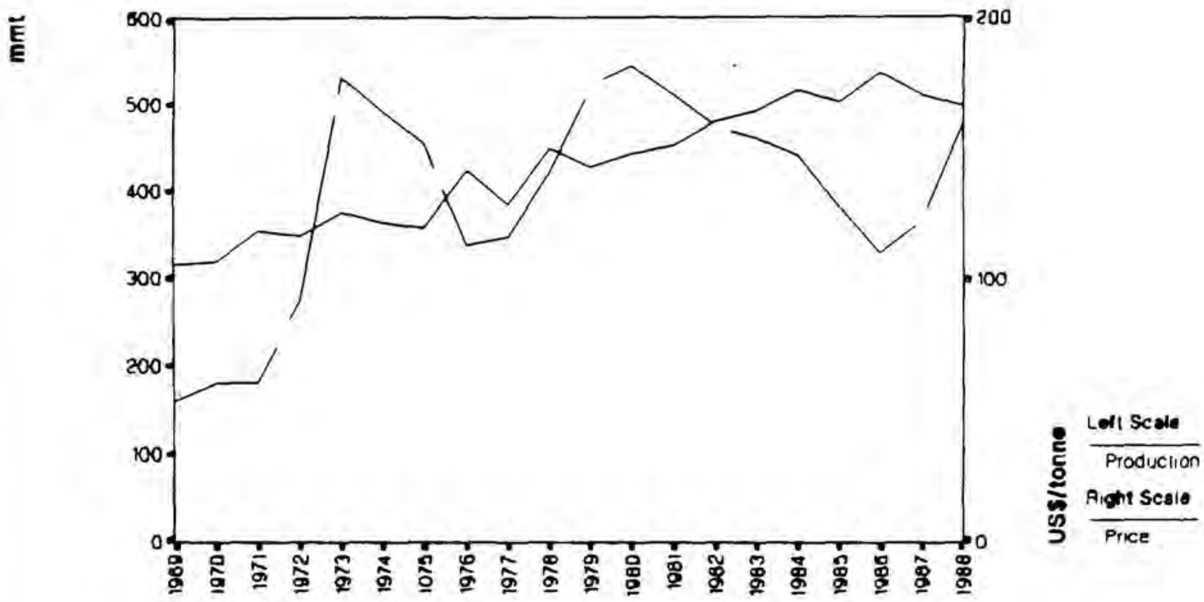
From 1966 to 1986, world production of wheat increased from around 250 to over 500 million tonnes (mmt), an increase of around 3 per cent per annum. This is shown in Figure 3.1.

Production is spread over many countries. Asia produces 35 per cent of the total, Europe 21 per cent, North and Central America 17 per cent and USSR 17 per cent. The five single countries with the greatest production are shown in Figure 3.2.

World consumption has moved with production over the last 20 years, growing at around 3 per cent per annum. Consumption is, of course, more dispersed than production, with 40 per cent occurring in Asia, 20 per cent in Europe, 20 per cent in USSR, 9 per cent in North and Central America, 4 per cent in South America, 6 per cent in Africa and 1 per cent in Oceania. The distribution of consumption for 1986 is shown in Figure 3.3.

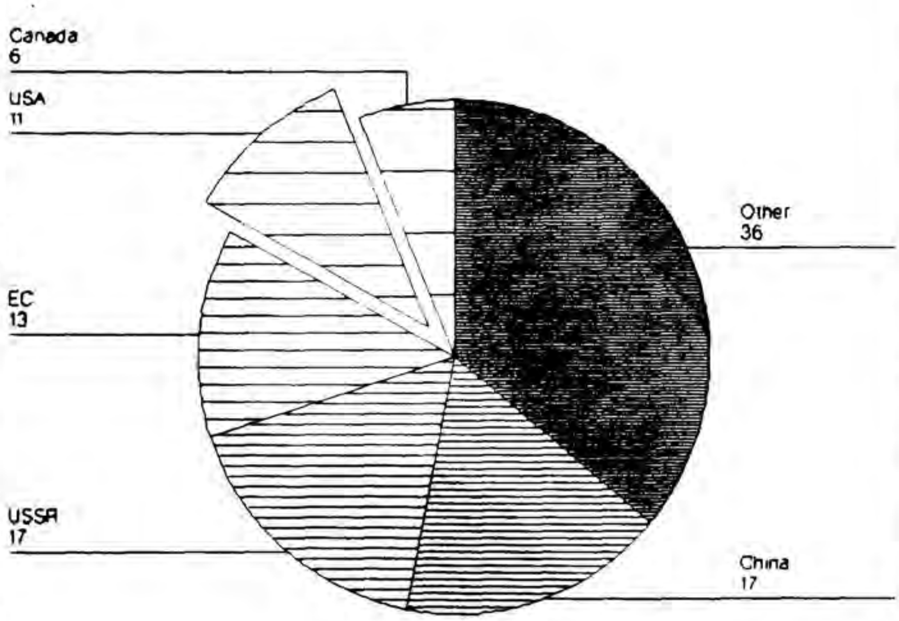
Most notably, developed countries produce 40 per cent of all wheat, yet consume only 25 per cent. This reflected the temperate nature of the crop, rather than the technological

Figure 3.1: World Production and Price



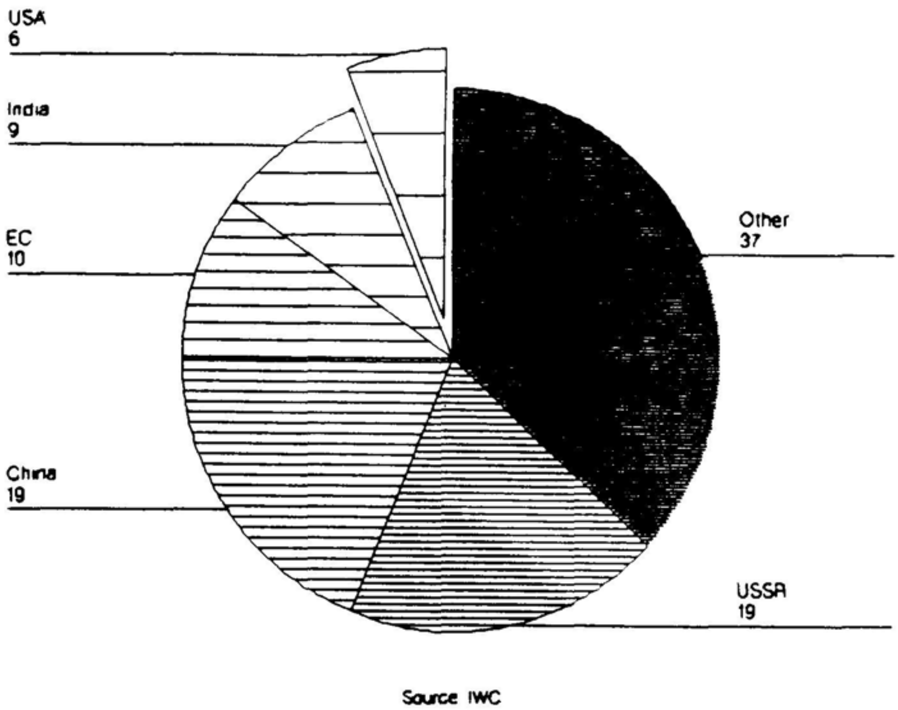
Source IWC

Figure 3.2: World Production Share by Region (Per Cent)



Source IWC

Figure 3.3: World Consumption Share by Region (Per Cent)



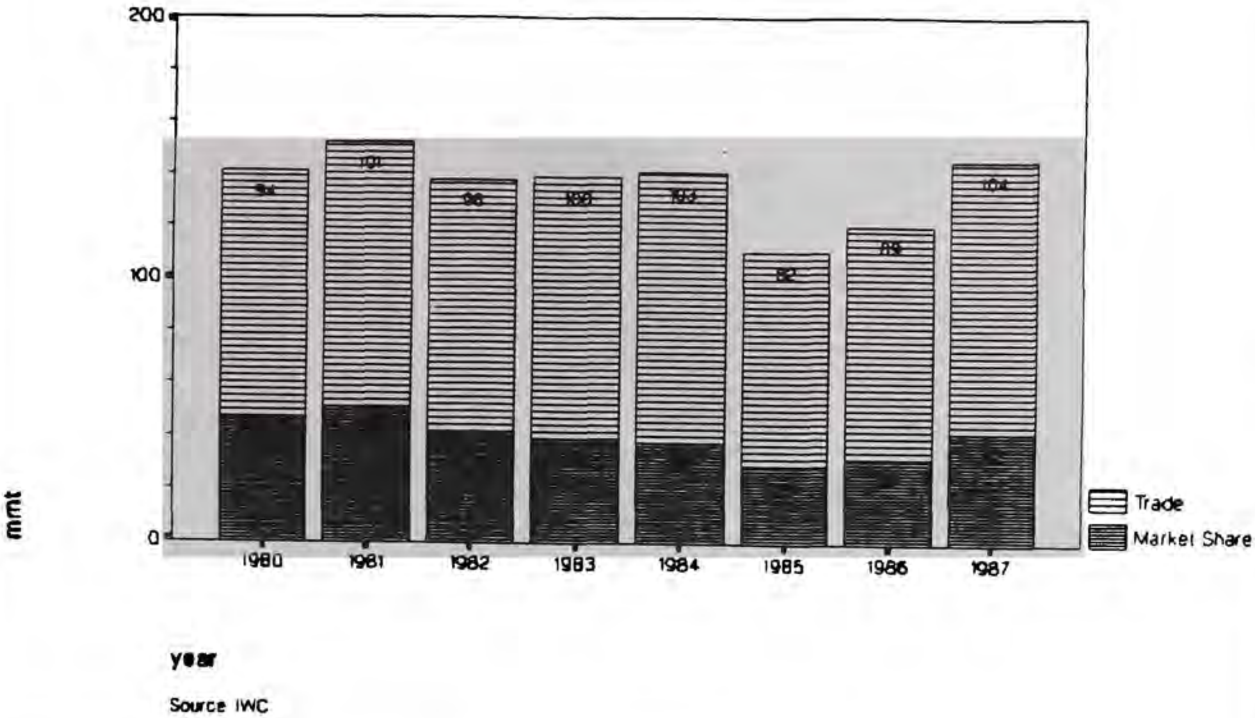
requirements. It implies that most of the wheat trade goes to less developed countries (LDCs) and centrally planned economies (CPEs). Import demand tends to vary inversely with domestic production. Hence, importers production policies are important. Balance of payments constraints and other macroeconomic considerations, and government policies which maintain domestic prices at levels above the world price have constrained the growth of consumption in the face of falling prices. An additional factor is the demand for feed wheat as an input into livestock production. This depends to some extent on the availability of coarse grains, which substitute for feed wheat.

3.1.2 Stocks

World wheat stocks have risen dramatically in the 1980s, in contrast with the equally dramatic fall in world prices. From around 20 per cent of production (or 100 mmt) in 1980, stocks rose to 158 mmt in 1986 (forecast 100 mmt in 1988[2]). This represents about 30 per cent of annual production. Stocks accumulated in response to policies designed

[2]Most of the data referred to in this section are from 1986, the latest year for which a consistent data set is available. 1986 is used as a base year in some of the dynamic analysis. Where current information is pertinent, reference is made in this chapter to more recent data.

Figure 3.4: World Trade and USA Market Share



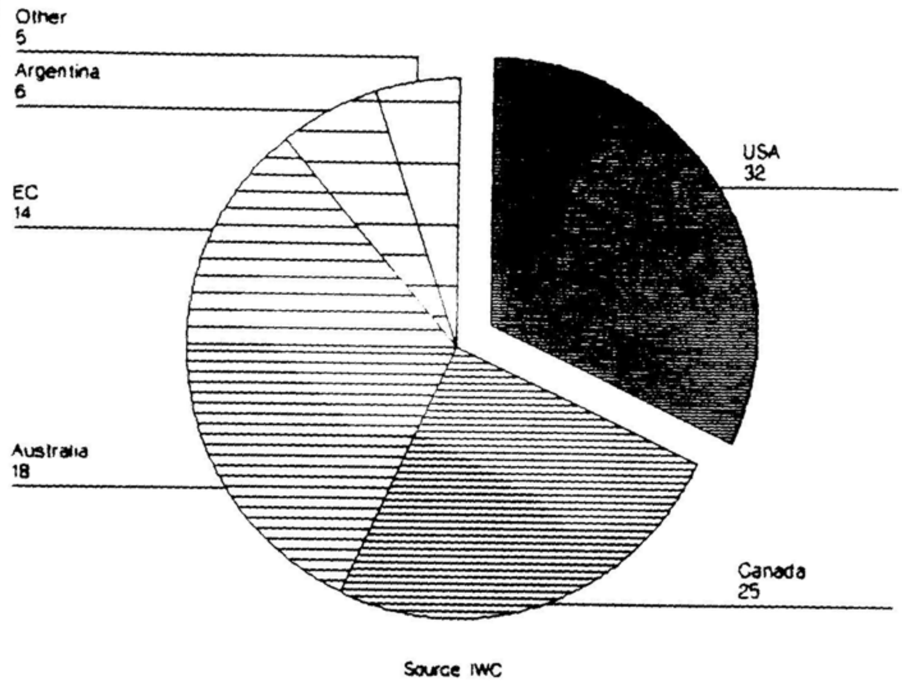
to provide income support. Stock changes in the USA and the EC are an incidental and largely unwelcome by-product of price support policies. In assessing the effect of stocks, it is necessary to examine the policies underlying their buildup. A description of national grain policies is presented in Appendix A.

The pattern of production, consumption and stockholding determines the trade flows between countries. The resulting pattern of trade is examined in the next section.

3.1.3 Trade

Wheat exports are dominated by just five countries, which supply 95 per cent of the market (1986). One of these, the European Community (EC), was a net importer in the 1970s. World trade in 1986-87 was 81.6 mmt, of which Australia exported 18.1 per cent. The American share of the world wheat trade has fallen from 51.2 per cent in 1981-82 to 28.9 in 1985-86. This is an important point, and is the basis for American claims that current policies aimed at retrieving market share are justified. Certainly, each of the other major exporters increased its share over the period. World trade and the USA market share is shown in Figure 3.4.

Figure 3.5: World Export Shares by Region (Per Cent)



Australia's contribution to world exports varies considerably. Market share amounted to 9.3 per cent in 1982-83, and 21 per cent in 1985-86. As the world market (volume) shrunk from its high in 1984-85, Australia increased its trade volume as the other exporters reduced theirs. Exports expanded from 11.475 mmt to 16 mmt. This is in spite of the falling world prices, and reflects yield increases and a diminution of stocks. Export shares are shown in Figure 3.5.

Wheat imports are, of course, far less concentrated than exports. In 1986-87, the major importers were the USSR (19.6 per cent), China (10.6 per cent), Japan (6.9 per cent), Egypt (5.6 per cent) and Korea (4.9 per cent). The USSR has been the dominant importer over the decade, and swings in import demand in the USSR significantly influence the world price. (Unfortunately, the opposite is not true.) Russian imports fell from 28.149 in 1984-85 to 16.400 mmt (Industries Assistance Commission (IAC) p. D.13) the following year, contributing significantly to the world price fall.

Over the decade, import shares have declined in South America and Asia, and have increased in the Middle East and Africa. This includes Iran , Iraq and Egypt, three of Australia's major customers.

An interesting feature of world trade is the large number of markets supplied by any one country. Australia is heavily dependent on a few importers, with six countries taking about 70 per cent of Australian exports (p. D.7). However, the remaining exports go to over 30 countries. A similar picture can be obtained by examining imports by source. With only 5 countries to choose from, no country sources more than 68 per cent of imports from the one supplier.

3.1.4 State trading

To exercise international market power, governments need to control quantities exported or imported. This may be done by controlling prices. One form of government control is through state trading. According to McCalla and Schmitz (1982), state trading refers to exporting and importing on terms determined by the government. It includes trading by government departments and corporations, producer marketing boards that have monopoly rights of acquisition, and trading companies with an exclusive license (p. 55). Almost all the grain trade involves a state trader, on either the export or import side.

Where state trading involves purely the marketing of the product, as in Australia or Canada, its significance for market structure is small. Production is not greatly affected by a producer marketing board. However, state trading is of more importance where the state determines the level of imports, or the amount produced or exported. Many centrally planned and developing economies have trading bodies with this function.

Since the 1960s, state trading of wheat by exporters has lessened, as the USA, which relies on private traders, has increased market its share. On the import side, however, the increasing demand from the centrally planned and developing economies has increased the importance of state trading. There is more private trading of coarse grains, as the USA is more important, and Australia and Japan (except for barley) do not 'state trade'. Furthermore, the developing countries import relatively less feed than food grain. Most importing countries appear less concerned with state trading in feed than food grain, no doubt due to concerns about food security.

McCalla and Schmitz note that while domestic rather than international concerns are prominent in the establishment of a state trading body, the desire to exercise market power probably exists in all state traders (p. 67). The extent to which this desire is fulfilled is dependent upon domestic objectives, among other factors.

3.1.5 Price formation

Thus far it has been noted that the international grain market is highly concentrated, particularly on the export side. Given this structure, what can be said about the way in which prices are formed[3]? The structure of the international grain market has led several authors to describe it as oligopolistic, with price leadership being provided by one or more of the major exporters.

An early attempt to explicitly take account of structure in the wheat market was that of McCalla (1966). This model was based on a cooperative duopoly between the United States and Canada, with other producers following the price determined by the two market leaders. Each exporter was assumed to accurately predict how others would react to its policies. The duopolists would act so as to maximise exports. The duopoly might break down following a reduction in demand, due to the constraint that the leader has some minimum quantity that must be sold.

Taplin (1969) criticised the specified objective of maximising exports, and maintained that Canada acted as a monopolist maximising revenue, while the USA followed in its price setting. Constant market shares were assumed. A stable oligopoly solution resulted from a kinked demand curve, although Alaouze, Watson and Sturgess (1978) noted later that this contradicted a prior assumption of product homogeneity.

Alaouze et al. contributed to the debate by proposing a triopoly, with Australia as the third dominant party. Their model is based on the assumption of minimum acceptable market shares, and cooperative behaviour between the USA and the price leader, Canada. When market shares are threatened, a limited price war is initiated, forcing Australia to restrain its exports. The stable equilibrium is obtained at the point of unitary elasticity on

[3]Futures markets have a role in price determination, but their role is primarily one of processing information, with identifying the location of the supply and demand curves, without determining the fundamentals. Thus, for the purposes of this analysis, futures markets are ignored.

the residual demand curve facing the triopolists. Significantly, the triopoly breaks down when *'selling the combined exportable surplus of the triopolists yields a price... which corresponds to an elasticity on the residual demand curve that is greater than unity'* (p. 182). Having identified the conditions under which the triopoly might degenerate into a price war, the authors noted periods of instability in stocks, prices and market shares which appear to support their argument. However, they did not construct an empirical model to test the relationships more formally.

While McCalla, Taplin and Alaouze et al. assumed market power is exercised by exporters, Carter and Schmitz (1979) postulated that an EC-Japan duopsony determined trade and prices. A more recent book by Schmitz, McCalla, Mitchell and Carter (1981) expounded this notion at greater length. In essence, they concluded that large importers impose an optimum, or near optimum, tariff, which transfers resources from exporters to producers and taxpayers in the importing country. The model was tested empirically, and the authors concluded that importers could be acting in a tacit collusive fashion in order to function as an importing cartel. Exporters were assumed not to retaliate.

Carter, Gallini and Schmitz (1980) examine the potential for export cartels among the major exporters in the wheat trade, and establish the conditions (that is, the relative elasticities) under which producers would gain from the formation of a cartel in which export taxes are used to constrain supply. The more significant the domestic market and the smaller the price elasticity of domestic demand, the less likely it is that producers gain. Consumers in export countries gain from a cartel, due to the fall in domestic price, while producer losses may outweigh the tax revenue (p. 817). The conclusion reached is that in contrast to products, such as oil, in which exporters have a very small domestic market, the formation of a cartel may lead to producers in member countries being worse off than at free trade, even though national welfare for the exporting countries has risen. This result is based on a comparison with free trade, and assumes no retaliation from importers.

McCalla and Josling (1985) note that importer cartels are faced with the problems of different cost relationships (implying different optimum prices) and the impact of price increases in switching some countries from importing to exporting. Indeed, since Carter and Schmitz's article, the EC has become a net exporter of wheat. McCalla and Josling maintain that the cost of importer collusion is high, due to the low concentration of importers, and hence the formation of an importer cartel is unlikely (p. 132).

While the McCalla, Taplin, and Alaouze et al. models represent useful, yet simplistic, departures from the perfectly competitive approaches, they have deterministic price formation processes. An indeterminate solution has traditionally been the main problem with imperfectly competitive models. In spite of solving this problem, the models lack any explicit dynamics to aid the determination of price. In a later article, McCalla, (1981) suggests that this is because the industrial organisation approach is focussed on market structure as the fundamental determinant of price. Welfare and policy considerations are excluded. By contrast, the cartel literature goes to the other extreme; structure is endogenous to the price formation process.

A further limitation of the models discussed so far has been the focus on either exporters or importers. Clearly, both have some degree of market power, especially if collusion is considered, and interactions between the two groups would appear to be a desirable feature of any realistic trade model.

Kolstad and Burris (1986) examine various market structures in the wheat trade, using a nonlinear complementarity programming approach to compute spatial equilibria. They compare various imperfectly competitive market structures (duopsony, duopoly and triopoly) with free trade. The duopoly and triopoly models explaine trade flows better than the free trade model, although the duopsony model performs poorly.

In their examination of the grain trade, Mitchell and Duncan (1987) conclude that whereas the rice and coarse grain markets conform to the dominant-firm oligopoly models, price leadership in the wheat market is shared between the USA, Canada and the Australia, with the other exporters taking the market price. Their analysis is based on data from 1965 to 1981, a period in which EC exports were minimal. The authors contend that the USA acted as a residual supplier, building up stocks when growth in demand was low, and running them down when the demand was great. The disproportionate sharing of stockholding by the USA was a function of the oligopolistic market structure. It reflects the role of the loan rate in underpinning the market price. As other exporters are prepared to let the world price fall down to the loan rate, the USA builds up stocks at that point.

Australia and Canada play a role in price determination when prices rise above the loan rate.

Taken together, these studies provide ample evidence that imperfectly competitive market models can be used to analyse the international wheat trade.

3.2 Government Intervention

The second necessary condition for conflict in international trade is government intervention. In this section, the nature and effects of trade and domestic policy are discussed. This facilitates an examination of the extent to which policies in some countries affect others. Such interaction provides the basis for a game-theoretic analysis. A detailed description of the national wheat policies of the main traders is given in Appendix A.

Trade policy reflects two games, one played at the national level, between various interest groups, and one at the international level, between trading partners and rivals. The two games are closely connected, with the outcome of each game influencing and being influenced by the other. In examining policy, it is tempting to categorise policies into domestic and international, depending upon whether the objective is to influence the allocation of resources within a country or between countries. Some policies, such as exchange rate changes, may appear to be aimed at altering trade flows and prices, but also have a significant effect on intersectoral resource allocation, especially between the traded and non-traded goods sectors. In analysing conflict, the dichotomy between domestic and trade policy is only important if domestic policies do not effect the world market. However, many domestic agricultural policies have a significant effect on production, and therefore do influence the international market.

What generalisations can be made in examining the agricultural policies of the major traders? Policies take a variety of forms, including deficiency payments, variable levies, tariffs, supply controls, export subsidies and taxes and various other measures. Generally, these policies mean that in developed countries, producer prices are well above the world prices, in the Japanese case by a factor of 10 for wheat. In developing countries, prices are often below the, already deflated, world price. It appears that countries which export most of their crop are orientated towards the international arena. By contrast, countries which consume much of their crop domestically are concerned to insulate their market from world trade.

3.2.1 Use of market power

Export taxes are the optimal method for an exporter to force up the world price and so capture some monopoly rents. Of the five major exporters, only Argentina has used export taxes, and these have recently been removed. However, the other exporters attempt to increase world prices by constraining supply. The USA has supply control, in the form of their Acreage Reduction Program, and Canada controls deliveries through a quota system. Australia has used production controls in the past. The EC has a range of measures to influence the prices received by the farmer, and hence supply, although the policies tend to encourage rather than constrain production. On the import side, a number of countries pay producers more than the border price, although the less developed countries tend to subsidise consumption. However, there appears to be little attempt to exercise market power on the import side. Most of the countries are too small to have a significant individual influence on the world price. The policies of USSR and China seem to be domestically orientated, with purchases being determined by domestic production shortfalls, rather than price.

3.2.2 Domestic market insulation

American and EC policies, plus those of some importing countries, insulate producers from market signals. Domestic prices don't move with world prices. During periods in which low prices and excessive stocks point to the need to reduce production, many countries have maintained policies which encourage production. This is because assistance measures are linked to output. Indeed, such a policy has turned the EC from an importer of wheat to an exporter. With domestic prices set at a level to provide sufficient income support for the marginal producer, the more efficient farmers produce quantities that cannot readily be sold on a depressed world market. Surpluses build up, requiring export subsidies for their depletion. Such subsidies are not only a burden to local consumers and taxpayers, but they depress the world market still further. The further prices fall, the more assistance is required. The IAC (1988 p. H.8) reports that in 1986 producer subsidies for wheat were: USA 90 %, Canada 25 %, EC 80 %, Australia 5% and Argentina -15 %. The US and EC policies are each estimated to have reduced the world prices by around 8 per cent. This was prior to the sustained use of export subsidies in 1987 and 1988.

3.2.3 Distributional effects of policy

Such policies are not only inefficient, but also inequitable. In the USA and the EC, the 25 per cent of the farmers receive 75 per cent of the farm support. In Japan, 20 per cent of the farmers obtain 60 per cent of the assistance. Most of the support goes to farmers who are wealthier than the average citizen, and in the EC the bulk of the subsidies go to the wealthier countries in the Community (ABARE p. 15).

3.2.4 Self-sufficiency

The desire for self-sufficiency has influenced production in a number of countries which have been importers for many years. The EC is a notable example, although the claimed need for self-sufficiency is sometimes viewed (by other exporters) as an excuse for other domestic policies. A number of Asian countries have made great advances towards self-sufficiency. China and India have increased production at a rate far in excess of the growth in consumption. In Asia as a whole, production has doubled over the last ten years. Under the Food Program of the USSR, wheat production is planned to increase to self-sufficient levels in the near future (IWC p. 37). If the target levels are met, the world grain trade will be substantially affected, as the USSR is currently the largest importer.

3.2.5 Reduced demand

Government interventions have also dampened demand. Many countries have domestic prices above world prices. Australia is an example of one such country, but more notable examples are the EC and Japan. Such a policy enables some of the cost of supporting farmers to be borne by consumers rather than taxpayers. Some countries use tariffs, levies or quotas to restrict imports. However, other countries, such as Egypt, subsidise consumption. The USSR subsidises consumption and taxes production (IAC p. 56).

Thus far the policies of the major traders have been looked at in isolation. However, the policies of one country may effect the welfare of other countries to a considerable degree, and this interaction leads to retaliation or other forms of strategic interaction between the trading countries when policies are set. This is the subject of this study. Strategic interaction is placed in historical perspective in the next chapter.

3.2.6 Policy interdependence

The interdependence between countries' domestic policies was noted, for example, by Josling (1977). There are numerous models which show how agricultural policies have tended to insulate domestic markets, and as a result have transferred instability on to the residual international market. Bale and Lutz (1979), Shei and Thompson (1977), and Zwart and Meilke (1979) confirm the relationship between domestic policies and world price instability. Although it is easy to see that national policies do effect the world market, the extent to which this occurs is not easy to determine. This is because certain policies have offsetting effects, not only because of substitution effects in production and consumption, but also because of offsetting international policies. For example, tariffs and export taxes tend to offset each other. The substitution effects, and the use of feed grain in livestock production, necessitate a multicommodity model.

An Australian study by the BAE (1985), using a multicommodity model, examines the impact of EC policies alone. The EC's policies, it is argued, depress and destabilise world prices by increasing production and the use of export subsidies, which aimed at ensuring that surplus production can be disposed of on world markets. The EC market is insulated, and thus it doesn't absorb fluctuations in supply or demand in the rest of the world. However, variations in EC supplies are absorbed in the world market. Prices of temperate agricultural products are estimated to have been depressed by an average of around 16 percent as a result of EC policies. This imposes a cost to the Australian economy of about $A1000m a year.

In examining the wheat trade, the IAC (1988) used two models to estimate international effects. The first was based on the Tyers model, developed by Tyers and Anderson. This model is well documented; see for example Tyers (1984, 1985, 1986) and, Tyers and Anderson (1986), and is a dynamic, global, multi-commodity stochastic simulation model. It has seven commodities and 30 countries or regions. However, it is not a general equilibrium model, and excludes non-agricultural sectors of the economy. Macro variables are included exogenously. The model includes public and private stockholding, and uses price transmission equations to incorporate the protection and insulation components of each country's policy.

The IAC used a static version of the Tyers model to estimate the net impact of wheat-related policies in 1986 on world prices. The overall effect was to depress prices by 16 per cent. A range between 11 and 18 per cent was obtained though sensitivity analysis. However, 1986 can be regarded as an unrepresentative year, with high stocks, low world prices and hence high nominal protection coefficients. If government intervention relating to all seven commodities is taken into account, the depressing effect on wheat prices is reduced to 12 per cent. Most of this can be attributed to policies in the USA and the EC. The results are not sensitive to changes in elasticities of up to 50 per cent. However, changes to the USA acreage reduction program do have a significant impact on the results, reducing the price-depressing effect from 16 to 13 per cent.

The IAC compared its results with those obtained from the OECD model. The wheat price depressing effects from wheat-specific interventions obtained from the OECD model are around 6 per cent, compared to their own estimate of 16 per cent. This reflects the 1979-81 data base, in which levels of protection are much lower than in the mid 1980s. In addition, interventions from non-OECD countries were not considered.

Thus far in this chapter it has been established that the oligopolistic structure of the market and the domestic policies of many countries, particularly the USA and the EC, lead to conflict situations. Before examining how such situations have been and could be analysed, a useful perspective can be gained by reviewing some examples of trade wars that have occurred in the last two or three decades.

3.3 Retaliation in Historical Perspective

3.3.1 The 1930s depression

The classic instance of a trade war occurred during the depression of the 1930s. This is an example of a many-player prisoners' dilemma. If each country attempts to obtain a free ride on the public good characteristics of free trade, a noncooperative Pareto-inferior outcome results. No players are happy with the outcome, yet they cannot improve their situation through reduction in trade barriers. Cooperation is necessary to resolve the prisoners' dilemma, and this normally evolves in repeated plays, when the game is iterated. This failed to occur in the Depression, due to the large number of players, and the fact that the biggest player in the game was a free rider. In 1930, the USA raised tariffs substantially under the Hawley-Smoot Act, in spite of the protests of many economists. Many of the tariffs were raised to prohibitive levels. Retaliatory action was widespread. Spain placed prohibitive tariffs on motor vehicles. Switzerland and Italy announced severe restrictions on imports from the USA. Canada imposed duties on 125 major products. World trade was severely reduced and the depression under this 'beggar thy neighbour' approach was unnecessarily severe and prolonged.

3.3.2 The chicken war

Because of these lessons of the thirties, trade disputes have been less frequent in the postwar period, at least until the oil crises and other macroeconomic factors destabilised world trade in the seventies. The 'chicken war' of 1963 was a notable exception. The EC restricted imports of frozen chicken. In response, the USA increased duties on cognac and light trucks. This game probably started out as a prisoners dilemma, but degenerated into a game of deadlock, as the EC continued to protect domestic producers even after the USA response. This was motivated, no doubt, by internal political pressures.

3.3.3 The cattle war

A similar dispute occurred between Canada and the USA over the cattle trade. The 'cattle war' of 1973 was initiated by Canada's attempts to protect its own industry by prohibiting imports of cattle which had been given a particular growth hormone. It followed up the non-tariff barrier by imposing quotas. The USA responded with its own quotas against Canadian cattle and meat. These disputes are described by Cline (1983 p. 138)

Trade wars are most commonly bilateral disputes. The best documented disputes seem to occur between large trading nations, such as the USA, Japan and the EC. Disputes between the USA and Japan relate to textiles in 1971, steel (1977), beef and citrus (1977-78), automobiles (1979-81), telecommunications (1978-80) and semi-conductors (1974-1984) among others.

3.3.4 The beef-citrus dispute

The beef-citrus dispute arose from a large bilateral trade imbalance, and Japanese import restrictions contravening the GATT agreement. (The USA also had beef import quotas, and quarantine constraints preventing the importation of Japanese oranges to all but six states, but these restrictions were not negotiated.) In 1977 the Americans pressed for greater access. Because of a skewed electoral system giving Japanese farmers considerable political power, the USA initiative met with strong resistance. After some months, Japan consented to a significant (three or fourfold increase) in various categories of orange and beef products. The USA dropped demands for full liberalisation, without informing American producers. When this knowledge leaked out some months later, greater pressure was placed on the American negotiator. A further series a talks led to a doubling of the quotas, but no agreement on complete liberalisation. The fundamental cause of this dispute, the trade imbalance, is still evident.

3.3.5 The EC-USA conflict

Several events have combined to increase the disputes between the USA and the EC in the 1980s. Falling demand, appreciation of the dollar in relation to other exporters and the policies of the EC led to a substantial loss in market share of the USA between 1981 and 1986 for agricultural products as a whole. With production incentives and export subsidies, coupled with significant yield increases, the EC became a net exporter of grain, sugar, poultry, eggs and dairy products. It is the use of export subsidies (restitutions) that has caused the most acrimony in America, and incidentally, in other exporting countries. In the mid 1980s, attention was focused on cereal substitutes, particularly EC non-tariff barriers on corn gluten, manioc and citrus pulp. With the addition of proposals relating to soybeans and vegetable oil, up to 60 per cent of USA agricultural exports to the EC were under threat of restriction (Purcell, p. xi). These restrictions were partly in response to the USA position on steel. In 1982 the Reagan administration prohibited the use of US technology in the construction of the Soviet-European gas pipeline (Wolf 1987 p. 208). For added leverage, the USA increased the countervailing duties, allowed under GATT, on steel imports from Europe. In response, the EC placed limits on imports of agricultural products.

3.3.6 An explanation

Conybeare (1987) attempts to explain trade wars using the notion of relative size. Size is effectively a proxy for the relative elasticities. He applies his analysis to some well-known trade wars, including the 1930s conflict, the chicken war between the USA and the EC in 1963, and the international steel conflict over the last two decades, in which the USA, the EC and Japan are the major protagonists. Conybeare emphasises the importance of asymmetry in size and the number of players in influencing the nature of the solution. As noted earlier, asymmetry leads to a noncooperative outcome, and an increase in the number of players reduces the likelihood of cooperation, as each player attempts to free ride on the cooperation of others. The approach fails to adequately explain seemingly irrational behaviour. Conybeare does not favour the welfare weights methodology, describing it as tautologous, a criticism relevant only for normative analysis. He relies on opportunity cost constraining politically motivated resource redistributions. This is not sufficient. Without welfare weights, he is unable to explain trade policies such as export subsidies.

The rationale behind import barriers is clear. Local industries, especially those located in politically sensitive regions, gain from the trade restrictions, at least in the short run. However, a feature of the grain trade in the 80s is the use of export subsidies. The rationale for their use is less clear, and is discussed in the next section.

3.3.7 Export subsidies

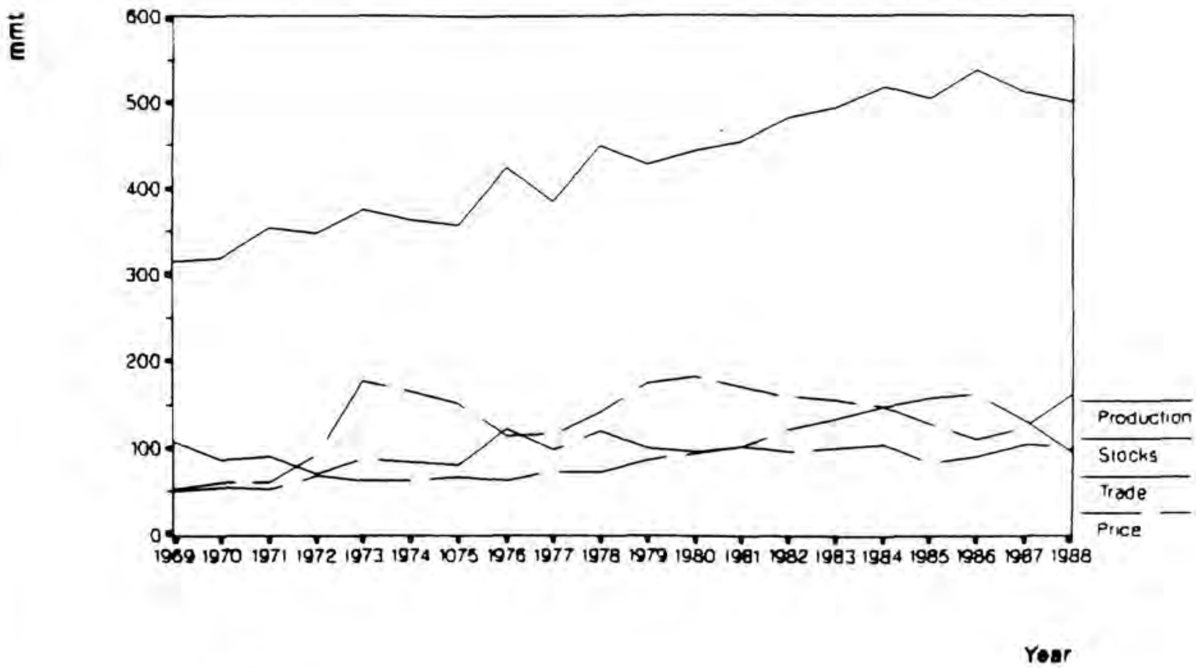
At present (1989), the most serious dispute in agricultural trade concerns the use of export subsidies. First, the progress of the export subsidy war is described, then consideration is given to its effects.

Examples of use

Export subsidies are any policy which allows a country to offer a price advantage when selling its goods on world markets. There are numerous examples of the use of wheat export subsidies. Paarlberg P.L. (1984) notes that between 1955 and 1966 about 30 per cent of all agricultural exports received some government assistance. More recently, in January 1983, the United States subsidised a sale of wheat flour to Egypt at $140-150/t below US market prices. The EC responded by subsidising exports of unmilled wheat to Egypt, and also to Iran, Syria, Libya, Algeria, China and some Latin American markets. The US ploy was singularly unsuccessful and expensive, with a direct cost of around US$180m.

In September 1986, the United States offered to sell 3.85 million tonne of wheat to the USSR at $87/t, well below the going world price of around $100/t. The EC responded with an offer of $76/t, and gained the sale. In the next year, the USA sold grain to the

Figure 3.6: World Production, Stocks, Trade and Price



Source IWC

USSR for \$80/t, with a subsidy of \$32/t. Although Congress approved the subsidies as '*a negotiating tactic to get Europe to reduce its subsidies*', they were soon being applied in markets unrelated to those with which the EC traded (Colebatch 1987). In 1988, with talks on reducing farm subsidies underway as part of the GATT Uruguay Round, the export subsidies continued. A subsidised sale of 2 million tonnes was negotiated in April. Meanwhile, trade talks centered on whether subsidies should be eliminated or merely reduced in the long term. The US-EC impasse was only broken when other countries threatened to scuttle the entire Round unless the two major traders agreed to consider the immediate problems of agricultural trade reform.

That subsidies exist, is readily apparent. What is not so clear is the effect of subsidisation. This has been the subject of much discussion.

Impact on prices

What happened to world prices during this period of substantial subsidisation? This is shown in the following graph. Of course, changes in production, consumption, stocks and trade are reflected in the world price and thus it it not possible to attribute a given amount of the movement in price to export subsidies.

Since the early 1970s, world grain prices have fluctuated considerably. Wheat prices doubled between 1972 and 1974 to US$177 and rose significantly from 1978 to reach record levels in 1981. From 1981 to 1987, prices fell steadily from US$182 to US$100. The influence of the US drought and various macro factors led to a strengthening of prices in 1988. Australian producers were somewhat protected from these declines by the depreciation of the Australian dollar. This halved the apparent price decline since 1984-85 (12 per cent in A$ terms. IAC p. 48).

Paarlberg R.L. (1986) discusses export subsidies as a response by the United States to EC export restitutions. A uniform subsidy on all wheat exports has large budgetary costs; impinges on small exporters such as Australia, Argentina and Canada; results in substantial windfall gains to importers, such as the USSR; and can be matched by the EC at one quarter the cost (p. 164). Targeting subsidies to particular countries is a cheaper option, but unlikely to be effective, as the EC can and does respond by targeting its subsidies at unprotected countries. All exports must be subsidised if increases in trade rather than changes in trade flows are to occur. There is little point in increasing the share in one market if it is lost in another due to retaliatory subsidisation.

Rationale for export subsidies

Analysis using the standard neo-classical competitive model suggests that export subsidies always reduce the welfare of the subsidising country. This is clearly the case in comparison to free trade. However, what if rival exporters are subsidising their exports? Is there be an argument for subsidisation on second-best grounds? Hartland-Thunland and Crawford (1982) suggest that there is a case for subsidisation in industries in which the country (the USA in this case) has a comparative advantage (p. 8). Subsidies keep resources in the efficient traded goods sector. More particularly, backward and forward linkages imply that subsidised exports induce a considerable future income stream. Sales of services and spare parts may be worth three times the value of the initial sale. This argument may be applicable to manufactured items, such as aircraft, but has little force in agriculture.

Paarlberg P.L. (1984) shows that within agriculture an export subsidy can be rational if sufficient weight is attached to producers in a weighted welfare function. Alternatively, an export subsidy can be used as a short term measure to '*limit future entry by other exporters or to drive out competition*' (p. 4). This use of market power will be successful only if rival exporters respond by reducing their level of exports. Finally, Paarlberg suggests that if export or total sales maximisation is the objective rather than welfare maximisation, then subsidies may be rational.

Gardner (1985), in a comment on Paarlberg's work, maintains that export subsidies are irrational, as more efficient policies could be selected to achieve the same objectives. In an earlier paper on this topic, Gardner (1983) points out that export subsidies may be effective as a means of reducing high and unanticipated levels of stocks. However, in the longer term, production controls and consumption subsidies may be a more effective means of reducing high stock levels.

In reply to Gardner (1985), Paarlberg (1985) claims that Gardner's preference for alternative policies over export subsidies is not unambiguous, and a different result can be obtained if consumers and taxpayers are treated as separate groups in the weighted welfare function. If consumers have a lower weight than taxpayers, then export subsidies may be preferred to deficiency payments, as budget costs are smaller for the former policy.

Gardner's response to this (1988) is to show that two policies can be used in combination to achieve a better outcome. If a consumption tax is added to the deficiency payments scheme, then indeed, export subsidies are still irrational, given the objective is to maximise a (weighted) welfare function.

With subsidies a topical issue, Paarlberg extended the analysis in a co-authored article (Abbott, Paarlberg and Sharples 1987). In this article, the feasibility of targeted export subsidies is demonstrated. However, this relies on a number of assumptions. The first is that targeted subsidisation can be enforced; that is, the imports are not re-exported. Other assumptions relate to excess demand elasticities, exporter stocks, transportation costs and other distortions which insulate the market. These factors play a critical role in determining the optimal subsidy levels. If the income effect, the subsidy amount and the trade volume are low, then a targeted export subsidy may even raise the world price, benefitting non-subsidising exporters (p. 725). However, the major problem assumed away here is possible retaliation of rival exporters.

Salathe and Langley (1986) also provide evidence in support of export subsidies. Subsidies may be preferred if export elasticities are sufficiently high. However, they are 'preferred' in comparison with existing policies, not in comparison with free trade or alternative trade policies. Once again, the results rely on market segmentation and the absence of retaliation.

Can export subsidies be explained by strategic considerations? Could subsidies applied by the US encourage the EC to move towards a more liberal policy? Are subsidies responsible for getting agriculture on the agenda at the Uruguay Round? Public announcements concerning 'trade wars' lend support to the notion that the strategic effects of export subsidies are significant. It has generally been considered that large countries have a strategic advantage, as they have greater credibility to back up threats to export a large quantity. Export subsidies provide evidence that the trader is committed to remaining in the market place. However, Dixit (1986) notes that small countries may in some instances have a strategic advantage, especially if high prices rather than large quantities are of interest. The small country may take profits from its larger competitor by posing no real threat to expand. It is therefore not worthwhile for the larger trader to reduce prices at the margin to regain sales, as the prices of its inframarginal sales must also be reduced. However, it is doubtful if this argument could be applied to a homogenous product like wheat.

Collie and De Meza (1986) examine the strategic effects of export subsidies. Like Gardner, they conclude that although subsidies may be beneficial, other policies, such as export taxes or domestic price controls, are generally superior.

Export subsidies appear to be a second-best policy. Nonetheless, subsidies can be readily observed. A likely explanation is that they are a result of the piecemeal nature of policy, a politically acceptable, but unintended consequence of previous expediencies.

In this chapter the role of the structure and nature of the market in contributing to conflict has been noted. The two necessary sources of distortion to the perfect market are the use of market power, and the actions of governments. Some instances of retaliation have been described in detail. Explanations and counter-explanations for export subsidies have been presented. To explain the behaviour of the market, a model which accounts for the observed market structure and the policy environment is required. In the next chapter, the use of game theory to analyse agricultural trade disputes is examined.

Chapter 4

Previous Models of Strategic Interaction

4.1 The Analysis of Trade Policy

In recent years, economic analysis of trade policy has undergone a change. Krugman (1986) gives three reasons for this. They are the increasing interrelatedness of national economies, the increase in two-way or intra-industry trade and new methods for analysing imperfect competition. Methods developed to analyse domestic problems of regulation, innovation and consumer protection have provided a means of handling the problems raised by the changing nature of international trade. Techniques for analysing international steel or aerospace industries can be applied to agricultural industries, where government intervention enables the many firms in each country to act as one. In this chapter, developments in the analysis of strategic trade policy are traced.

Retaliation from a general equilibrium viewpoint is discussed first. Some static models of imperfect competition in the wheat trade are than assessed. In the third section, a Cournot-Nash model with welfare weights is examined. Conjectural variations and dynamic models are described in the remaining two sections.

4.2 A Trade-Theoretic Perspective

4.2.1 Early analysis

Optimal tariff theory has a long history. Conybeare (1985, p. 25) notes a sixteenth Century mercantilist treatise supporting high tariffs because foreign countries were unlikely to impose a retaliatory tariff on English exports, which had a low elasticity of demand. Bickerdike (1906) argued that a tariff could raise domestic welfare. This was largely ignored, however, as many economists believed it was impossible to choose among alternative trade policies, from a national perspective, due to an inability to assess the distributional impacts. This stemmed from the difficulty in making interpersonal utility comparisons. As free trade had been shown to be best for the world as a whole, it was considered to be best for single countries as well. Following Kaldor's (1940) assertion that countries may gain from trade even in the presence of retaliation (depending upon relative import demand elasticities), Scitovsky (1942) developed the community indifference curve analysis to assess trade policies. He assumed that two countries will eventually recognise their interdependence, and an indeterminate (cooperative) bargaining situation will prevail (p. 102). When there are many countries, this interdependence is harder to recognise. Without explicitly specifying his equilibrium, Scitovsky nonetheless concluded that *'every country will actually be impoverished as they all raise their tariffs'* (p. 109). Thus, it is necessary that free trade be enforced, rather than left to market forces.

Johnson (1953-4) formalised Scitovsky's work, and by having traders respond in a Cournot-Nash fashion, outlined the special supply and demand conditions under which one country may be better off after a tariff war than with free trade. However, in the standard case, both countries would be worse off following retaliation. For simplicity, Johnson assumed that the offer curves (reflecting the import demand and export supply) were of constant elasticity form, implying that a change in a rival's tariff did not alter one's own optimal tariff. Gorman (1957) extended Johnson's analysis using the same constant elasticity assumption. With retaliation having no effect on the tariff, the Cournot-Nash equilibrium is easy to compute. However, the underlying assumption of constant elasticity is dubious, and very difficult to derive from sensible supply and demand curves (Whalley p. 234).

4.2.2 Extensions

Panchamukhi (1961) showed that Johnson's and Gorman's analysis is similar to a two-person non-zero sum game, opening the way for game-theoretic analysis in this area. McMillan (1986) notes several further refinements of Johnson's analysis, including the application of specific rather than *ad valorem* tariffs (Horwell 1966); the use of tariff revenue as the decision variable (Weymark 1980); and the conditions necessary for the existence of equilibrium (Kuga 1973 and Otani 1980). Rodriguez (1974) showed that whereas tariffs and quotas are equivalent under competitive conditions, this is not so in the presence of retaliation. Tower (1975) demonstrated that if quotas are used retaliation will always lead to zero trade. Other refinements include consideration of capital flows (Jones, R.W. 1967), labour markets (Batra 1977), and domestic distortions (Jones, A.J. 1987).

4.2.3 Imperfectly competitive industries

Much of the current literature on imperfectly competitive markets examines situations in which industries (rather than nations) are better off even after retaliation has occurred than in a free trade situation. A useful guide to this literature is Krugman (1986). Brander (1986) describes the rationale for strategic trade policy. Losses (subsidies) may be sustained in the short-run to keep rivals out of the market place, or to provide evidence of a commitment to stay in the market. Governments may have access to tools (for example, export subsidies) that are not available to firms or industries (or small governments). If other governments respond to a subsidy, as is to be expected, game-theory is required to analyse the variety of possible outcomes. Brander's conclusion is that there is no one best policy, and each case is dependent upon the characteristics of the industry (p. 44).

4.2.4 Multilateral trade negotiation

Game-theoretic analysis has been applied to multilateral trade negotiations in a number of studies. A feature of these models is the specification of the objective functions. In an assessment of the Tokyo Round, Chan (1985) assumes negotiators attempt to maximise a function composed of static welfare gains plus the balance of trade. He examines three cooperative solutions, and concludes that an egalitarian solution best fits the actual outcome. Equity dominates efficiency, possibly because sidepayments were not possible. Baldwin and Clarke (1987) specify an objective function which includes the variability of tariff rates across products, the average level of tariffs, reciprocity (each country reduces tariffs by a similar amount) and equal protective levels in each sector. Each country attempts to minimise the weighted average welfare loss from not satisfying these incompatible criteria. The weights on the welfare function are obtained by examining reform proposals. Cooperative and noncooperative solutions are obtained. These yield welfare losses similar to the proposals put forward by the individual players. However, actual post-Tokyo Round positions are much inferior to the game solutions or to the proposals because of requested exceptions from the general formula. This reflects domestic political pressures in implementation of the agreement. The authors note that weights attached to welfare attributed to individual sectors would have probably improved the results.

Whalley (1985, Chp. 14) examines the outcome of an optimal tariff war between the USA, the EC and Japan. Optimisation of unweighted national welfare is the objective. Whalley shows that large countries, with large elasticities of demand for imports, have a higher optimal tariff than small countries. With equal sized countries, tariffs at between 150 and 200 per cent raise welfare by about 2 per cent in the absence of retaliation. If tariffs are imposed simultaneously in each country, global welfare falls by about 4 per cent. Whalley's work indicates that optimal tariffs are very high, much higher than observed tariffs, that trade wars can lead to substantial losses, and that the power of large countries in their negotiations with nations with limited size is considerable. This points to the advantages of cooperation for small trading nations.

Harrison and Rutström (1986) compute numerical noncooperative Cournot-Nash solutions in a general equilibrium framework. They first apply simple games with two players and two strategies, namely abolishing trade barriers or maintaining them at their current level. The introduction of mixed strategies requires a combinatorial algorithm to identify the sets of tariff levels at which welfare is calculated. This is a limitation of a numerical approach, but is unavoidable because of the size and complexity of general equilibrium models. The model is used to determine the outcome of tariff wars involving two or three countries. A feature of their results is that welfare losses due to a trade war are very small. A 100 per cent across-the-board tariff imposed by each country leads to a change in welfare of only 0.1 per cent. This no doubt reflects the importance of the non-traded goods sector. Secondly, large countries were found not always to win a tariff war. There are Nash solutions in which both countries lose. However, because of nonlinearities in the model, the Nash solutions obtained are not unique. In spite of the limitations, the model is a promising attempt to apply game theory to real world problems.

The approaches outlined in this section are general, rather than partial, equilibrium. Much theoretical analysis is conducted in a general equilibrium framework, using offer curves to derive the optimal tariff. However, empirical work often utilises a partial equilibrium framework. The correspondence between the two is demonstrated by McMillan (1986 pp. 26-28) and Kindleberger and Lindert (1978 pp. 511-12). Partial equilibrium models are reviewed in the following sections.

4.3 Static Models

In spite of these new insights, reviews (by Thompson (1981), Blom (1982), and Sarris (1981) for example) of wheat trade models illustrate the popularity of competitive spatial equilibrium models for examining issues such as price stability, trade flows and welfare distribution (Zwart and Meilke (1979), Shei and Thompson (1977), Grennes, Johnson and Thursby (1978) and numerous others). These approaches ignore the possible effects of retaliatory interactions between a small number of traders, the problem being assumed away with the specification of the markets as competitive.

In the applied area a number of modellers of imperfect competition have imposed arbitrary or ad hoc assumptions regarding expected response.

The models of McCalla (1966), Taplin (1969) Alaouze, Watson and Sturgess (1978) and Carter and Schmitz (1979) were mentioned in Chapter 3. These models assume some degree of imperfect competition, and rely on an ad hoc mechanism for specifying the formation of prices. These models have made a significant contribution in leading to ways of thinking about the imperfectly competitive nature of the market, and provide a basis for further developments.

Models of cooperative behaviour, such as those discussed here, introduce possibilities of cheating, deterrence and side-payments, and increase the number of possible solutions. The solution to these models depends more on the assumption regarding collusive behaviour than on the nature of retaliation.

4.4 Weighted Welfare Functions

Sarris and Freebairn (1983) incorporate interaction between traders in their model of the world wheat trade. The model emphasises the bargaining process by which various groups (producers, consumers and taxpayers) attempt to extract resources from the government, within a centralised policy making framework. A revealed preference approach is used to determine the welfare weights attached by policymakers to various objectives. While this approach emphasises the influence of government intervention, rather than market power, the determination of international prices within the model depends on the Cournot equilibrium assumption. However, the solution attained in the model cannot really be described as Cournot. Although elasticities are less than infinite, Sarris and Freebairn assume that countries behave as if there was no response. This assumption leads them to maintain that if the weights are equal, and if there is no concern about domestic price stability, *'...the optimal policy for the country is a free-trade one'.* (p. 216) It will be shown later that a free-trade solution only maximises the country's welfare if the country lacks the market power to influence world prices. This is the so-called small country case, where the elasticity of demand facing the exporter approaches infinity. In Chapter 5, this deficiency in Sarris and Freebairn analysis is rectified.

4.5 Conjectural Variations

The models described so far do not address the problem of expectations of retaliation. However, as noted in the previous chapter, one of the limitations of the conjectural variations analysis is the multiplicity of solutions, one for each type of market structure under consideration. A method is needed to determine just what expectations of rivals' responses are held by each player.

Thursby and Jensen (1983) take a somewhat ad hoc approach. Using a static two-country, two-commodity model, they impose arbitrary conjectures and derive the resulting optimal tariff equilibrium; a variant of Cournot-Nash conditional upon given (constant) conjectures. Suppose Country A is considering changing its tariff t_a. It expects Country B will change its tariffs t_b such that the resulting percentage change in t_b will be a constant proportion of the percentage change in the terms of trade induced by A's change of t_a. With the aid of considerable algebraic manipulation, Thursby and Jensen arrive at the intuitively pleasing conclusion that increased expectation of retaliation results in lower equilibrium tariffs in both countries. Hence, the Cournot-Nash assumption of zero expectations of retaliation overstates the cost of trade wars.

From a modelling perspective, a promising line of inquiry is that taken by Kolstad and Burris (1986), and referred to earlier. A nonlinear complementarity programming approach is used to compute spatial equilibrium in oligopolistic or oligopsonistic markets. They show how conjectural variations estimates can be utilised; however, for their purposes they assume conjectural variations to be zero, the Cournot assumption.

Perhaps the most impressive attempt to incorporate conjectural variations is that of Paarlberg and Abbott (1986). They assume policymakers hold conjectures regarding the slope of the excess demand function (response function) and derive domestic and trade policies from these conjectures. The policies also reflect the strengths of various interest groups. This analysis utilises the Thursby and Jensen methodology, except that conjectures are determined endogenously, instead of being imposed. In fact, their conjectures are a direct function of rivals' policies, as a long run equilibrium in which actual implemented policies relate to expectations of rivals' behaviour is assumed. This is not necessarily a consistent equilibrium, as conjectures may be only weakly related to actual behaviour.

A revealed preference methodology is used to estimate conjectures from observed policies and the first order conditions of the model. Conjectures reflect domestic as well as trade distortions. The analysis is applied to a seven region wheat model. In spite of some counter-intuitive estimated conjectures, the model is a useful attempt to endogenise policy, and to assess the impact of oligopolistic rather than competitive behaviour.

4.5.1 Consistent conjectural variations

Models with constant conjectural variations, such as Thursby and Jensen's, do not adequately handle the problem of conjectures being inconsistent with observed responses. A trader observing its rivals over time should hold conjectures consistent with those observations. This implies that expected behaviour is equivalent to actual behaviour. Bresnahan (1981), Perry (1983) and others developed the concept of consistent conjectural variations in a duopoly context. Kamien and Schwartz (1983) generalised the model, showing the specific conditions (relating mainly to the functional form of the reaction function and demand and cost functions) necessary for this equilibrium. In addition to its intuitive appeal, a further attraction of consistent conjectural variations is that the number of possible equilibria is very much reduced. In spite of its appeal, the equilibrium is restrictive (in the conditions required for a stable, unique solution) and mathematically cumbersome, especially when players have differing (asymmetric) cost functions. For these reasons this equilibrium is not used here. The approach used involves estimation of conjectures from observed behaviour.

One solution to the problem of specifying conjectures is to use dynamic games. These are reviewed in the next section.

4.6 Dynamic Game Models in Agricultural Trade

This subsection contains a brief review of dynamic game models that have been applied to agricultural trade problems[1].

The use of dynamic games is becoming increasingly popular in industrial organisation and macroeconomics (for example the problem of assigning instruments to targets, as illustrated by Pindyck (1977), and the macro linkages between economies are problems that have been analysed with dynamic games). To date, however, there have been few applications in the area of international trade.

The most significant application of dynamic games to international trade is by Karp and McCalla (1983), and Karp (1987a), who develop a dynamic difference game model of the world corn (maize) market. Karp and McCalla postulate a simple linear cobweb model, with supply a function of lagged price and tariff. The tariff (or export tax) may be positive or negative. Welfare to be maximised is a function (with linear and quadratic components) of current and lagged prices and tariffs for all countries. They find a noncooperative Cournot-Nash equilibrium, assuming feedback controls which imply that each player takes into account how its rivals will respond.

Karp and McCalla apply their model to the world corn market, assuming three main players (the USA, EC and Japan, with the rest of the world as a residual). They found that in a Nash game, the only exporter (the USA), would subsidise exports in the initial years and switch to a tax in the later years. The USA benefits from a tax stretching from the end of the time horizon (20 years) to infinity, after having reduced the competition with a subsidy in the early years. Results were sensitive to the time horizons of less then about 15 years. Retaliation by Japan led to an increase in taxes in the USA and an ambiguous response by the EC (depending upon the Rest-of-World demand elasticity). Each country benefits from trade barriers, and benefits are greater if rivals do not respond. Specifically, the USA reduces its taxes in response to an EC tariff increase. Both the EC and Japan increase their tariffs when the USA reduces its export taxes.

[1] Surveys of the application of control theory to economic problems can be found in Kendrick (1976), and Pitchford and Turnovsky (1977). A reference which provides a comprehensive treatment of dynamic noncooperative games is Basar and Olsder (1982).

In response to lagged prices, the importers increase tariffs and the USA reduces its tax when the previous periods world price was high. This reaction tends to stabilise prices. Likewise, changes in tariffs tend to stabilise imports and exports. Thus, Karp and McCalla noted that there is no reason why a trade war would eliminate trade, even though global welfare may be significantly reduced.

These results are consistent with those obtained from a static model. The most interesting result is the switch in policy (from subsidy to tax) over the time horizon. The effect of lagged prices and tariffs is also noteworthy, pointing to the need for careful specification of the lag structure.

Karp (1987b) generalised his earlier co-authored work to include risk. Unfortunately, the results were not generalised. Karp was unable to conclude that increased risk aversion led to a less aggressive trade policy. The effect of risk on a rival's tariff was also found to be indeterminate.

The model presented in Chapter 7 is similar to that of Karp and McCalla (1983), although it differs in a number of respects. The model contains a two-period lag, allows for differing weights on the economic surplus going to various groups, is solved by a quite different solution algorithm, and is applied to a large number of players involved in the wheat, rather than corn, trade.

A recent paper by Ahmadi-Esfahani and Carter (1987) treats the USA as a dominant supplier, and the remaining exporters as a competitive fringe. Market shares are examined in a dynamic framework. Optimal control is used to determine the pricing structure which maximises the present value of expected profits, given that high prices will encourage foreign producers to enter the industry, thus limiting the short-run profits. A limit-pricing strategy will discourage entry, ensuring a low level of long-run profits. The optimal strategy depends upon the discount rate, the relative cost structures and the elasticity of supply of the competitive fringe. If the US has a cost advantage, it may pay to drive out competitors with low prices. In the extreme, it may be rational to take current losses to increase market share and hence long-run profits. This analysis of market shares extends the static analysis in an important direction, but is focused on the USA as the only country with market power. Retaliation by other exporters or importers is ignored.

The work presented in the following chapters builds on previous work discussed in this chapter. In particular, the static analysis of Sarris and Freebairn (1983) is extended in Chapter 5. The conjectural variations model developed in Chapter 6 derives from the work of Paarlberg and Abbott (1986), and the dynamic analysis of Chapter 7 is based on Karp and McCalla (1983).

Chapter 5

Static Trade Games

It is apparent from Chapter 2 that there are a variety of game-theoretic approaches by which retaliation can be analysed. In this chapter[1] the assumptions underlying the game-theoretic model to be developed are discussed. The static model is then derived, the solution procedure explained and the model applied to the world wheat market.

5.1 Assumptions

Important assumptions common to all versions of the model in this study include:

- noncooperative behaviour,
- linear and deterministic supply and demand schedules,
- welfare optimisation[2],
- use of trade taxes as a control variable,
- product homogeneity,
- annual periodicity, and
- zero cross-commodity effects.

[1] Some of the material in this chapter appeared in Vanzetti and Kennedy (1988a).

[2] An exception to this is a market shares model presented in Section 5. This model does not have welfare maximisation is the objective.

These assumptions are examined in some detail.

5.1.1 Noncooperative behaviour

In contrast to some previous models of the wheat market, cooperative behaviour is assumed not to exist. This is a convenient assumption, from the point of view of obtaining unique solutions, but it can be justified by the absence of binding and enforceable agreements in agricultural trade, at least between rival exporters or rival importers. While there is some evidence that the General Agreement on Trade and Tariffs (GATT) has led to substantial reductions in trade barriers for some goods, this cannot be said for agriculture. Indeed, in spite of many multilateral agreements, there is evidence of a marked lack of cooperation. Throughout the 1980s, while Australia, Argentina and the USA reduced wheat production in response to falling world prices, Canada and the EC increased output. Another example is the 1980 embargo of grain sales by the USA to the USSR. Gardner (1988) notes that there is no evidence that the embargo had any effect. It led merely to a trade diversion, as other exporters filled the gap. This is supported by Paarlberg, R.L. (1987), who maintains that the embargo hardly affected grain trade from the US, let alone non-participating exporters. The embargo failed under conditions *'uniquely favourable to its success'* (p. 185). An example of attempted cooperation is the formation of the Cairns Group, including Australia, Canada, and 12 other exporters of temperate products. Within two years of its formation, Canada effectively reneged on the agreement by providing substantial subsidies to its impoverished grain producers. It appears then, that the assumption of noncooperative behaviour is not unrealistic.

5.1.2 Linear supply and demand

In this study, the demand and supply curves are assumed linear. While linearity is somewhat unrealistic, the effect of this assumption is probably dominated (at least for small changes) by the effect of errors in parameter estimation. The advantage of linearity is that the objective function is quadratic. In the dynamic model, the constraints, linking prices from one period to the next, are also linear, in addition to being equalities. This implies that the problem of finding optimal tariffs for a single country can be regarded as the familiar linear quadratic programming problem. Such problems can be solved quite readily using analytical or numerical techniques.

A disadvantage of linear supply curves is that with elasticities less than one, the supply curve cuts the horizontal axis, implying positive supply at zero price. On the demand side, the elasticity increases as the price increases, a counterintuitive effect. Furthermore, a linear curve is likely to overstate the reduction in consumer surplus due to a price increase. These factor need to be borne in mind when interpreting the results, particularly if price changes are substantial.

5.1.3 Deterministic supply and demand

The model to be specified is deterministic. There are no error terms in the supply and demand functions. All parameters are known by all players with certainty. This is possibly the most unrealistic assumption. Certainly the real world is stochastic, and issues of risk and stability are important considerations. However, this restriction is not as limiting as it may seem. Chow (1981, p. 47), in discussing dynamic problems, notes that the certainty equivalence solution for the current control is optimal for the multiperiod stochastic control problem given a quadratic objective function and a linear model with additive disturbance terms. Models with stochastic terms can be reduced to 'certainty equivalence' models, which are much easier to handle, by setting the random disturbance terms equal to their expectations. Nonetheless, the model developed here can best be seen as preliminary to more comprehensive analysis with stochastic disturbance terms.

5.1.4 Welfare optimisation

The strategy followed by each player involves optimising a welfare, or criterion, function, in which weights can be attached to the surplus attributed to consumers, producers or taxpayers[3], following the approach used by Sarris and Freebairn (1983) and Gardner

[3] The weight applicable to taxpayers, denoted w_g in later analysis, relates to tariff and export tax revenue, and subsidy expenditure. The terms 'taxpayers' and 'government' are used interchangeably to

(1983). Rausser, Lichtenberg and Lattimore (1983) discuss the use of criterion functions as a means of endogenising government behaviour. Within agriculture, emphasis must be on the level rather than choice of policy. Interest groups, rather than electors, influence bureaucratic decision-makers. Rent seeking interest groups compete in a political market for economic resources. Thus, there is a strategic game being played between the various interest groups. Each industry prefers protection for itself, but not for other sectors which compete for resources. Once again, the large number (of individual consumers and tax-payers) and asymmetry problems are evident, leading to a noncooperative solution that may not be in the national interest. The preference function approach is based on the assumption that the game at the domestic level has been played, and the policymaker has a stable, weighted welfare function to optimise. Domestic conflicts are not assumed away, but relegated to another level. This reconciles the multitude of interest groups with the implicit assumption that there is only one actor in each country playing the trade game.

Weights attached to the preference function can differ from period to period. For example, policymakers may attach a greater weight to the surplus attributed to producers in the period immediately prior to an election. In other periods, the budget constraint may be of greater concern, and greater significance may be given to the government surplus. If the weights attached by policymakers can be determined, a greater understanding of the decision making process can be obtained.

No account is taken of the welfare of other countries, be they political allies or opponents. The recent sales of subsidised wheat by the USA to the USSR, with an indirect cost imposed on other exporters, including Australia and Canada, lends support to this assumption.

It is assumed that purchasers of wheat make up a small part of an individual's budget, and hence there are no income effects. Furthermore, balance of payments and other macro effects are ignored. The exclusion of macro factors is harder to justify, especially for countries which depend heavily on exports of wheat. A general equilibrium approach would no doubt be more satisfactory in some ways, albeit less tractable.

refer to this group.

5.1.5 Tariffs as decision variable

In most of this work it is assumed that a (positive or negative) unit tariff[4] is the policy instrument by which countries attempt to alter world trade. In contrast to much theoretical work, such as that of Thursby and Jensen (1983), which uses *ad valorem* tariffs, empirical models, such as those presented in Karp and McCalla (1983) and Sarris and Freebairn (1983), often feature unit tariffs. This has the advantage that the unit tariff can represent a range of policy instruments which result in an additive differential between world and domestic prices.

The theory of the optimum tariff postulates that if the border price of imports falls when a tariff is imposed, then it is possible, in the absence of retaliation, for an importer to increase welfare by imposing some positive tariff. The tariff is optimal only in a national sense; global welfare decreases.

The impact of the tariff can be seen in Figure 5.1. Domestic prices have risen to P_1, while the border price has fallen to P_2. Consumption and imports have decreased, while domestic production has increased. Consumer surplus decreases to afP_1, producer surplus increases to beP_1, and tariff revenue is $efih$. As tariffs increase, producers and the government gain at the expense of consumers. At the optimum tariff, the revenue attributable to the decrease in imported prices, the shaded area $klih$, equates at the margin with the deadweight losses, the triangles egh and fij. Note that export subsidies cannot be welfare improving, as there is no tariff revenue to offset the deadweight losses that accrue immediately domestic prices rise above world prices. Indeed, export taxes are the preferred policy instrument for exporters which can influence the world price.

The appropriate reaction of an exporting country A to an import tariff in country B is a further tariff applied to exports from country B to A. By this means, country A can turn the terms of trade in its favour, so long as no further retaliation occurs. However, instead of an import tariff, retaliation can also take the form of an export tax, as this has a similar impact on the terms of trade. (This equivalence between export and import taxes is known as Lerner's symmetry theorem.) With market power and no retaliation,

[4]Here, the term 'tariff' is sometimes used to refer to export taxes in addition to import taxes. Export taxes are expressed as negative tariffs.

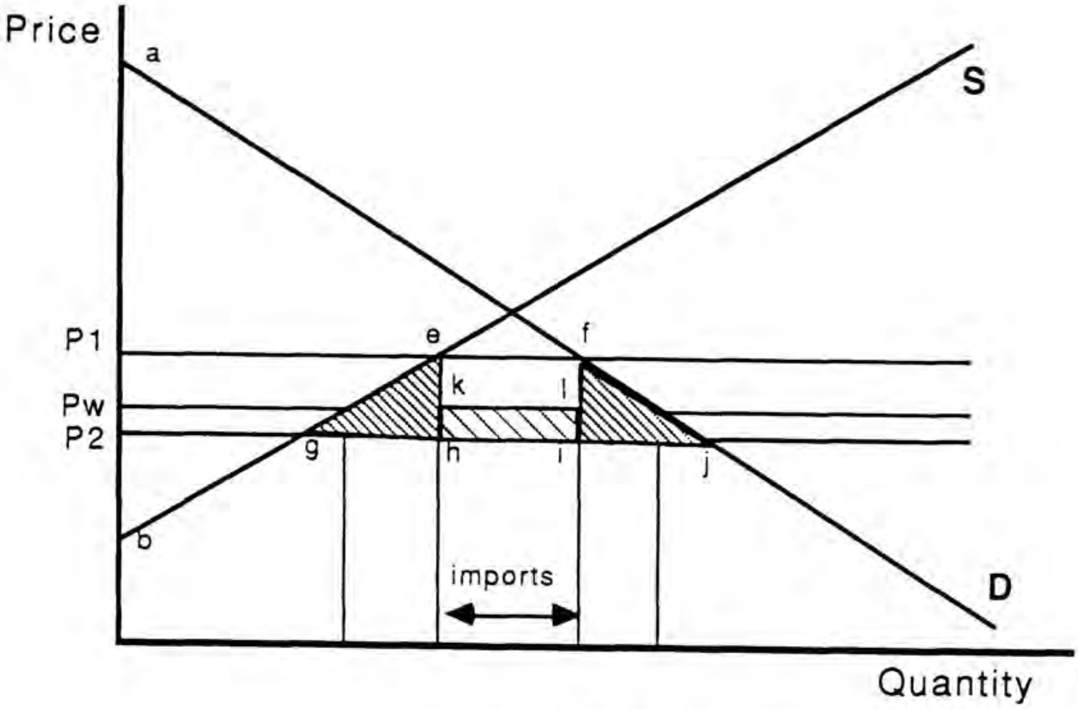


Figure 5.1: Impact of the Tariff

an exporter's optimal trade policy is an export tax, not an export subsidy.

A range of policies have similar effects as a trade tax. Coyle, Chambers and Schmitz (1986) maintain that the US loan rate program, the deficiency payments scheme and the acreage reduction programs act as an implicit export tax, export subsidy and export quota respectively (p. 14). For example, the deficiency payments program raises domestic prices and leads to a decrease in world prices, resulting in a reduction in trade gains. Export subsidies have an effect which is similar.

Export taxes appear to be uncommon in international trade, at least in developed countries, which are inclined to protect their agriculture. In fact, such taxes are unconstitutional in the United States. However, export taxes may take less explicit forms. Gardner (1988) notes that a joint consumer subsidy and producer tax will have a similar effect as an export tax (p. 40). An overvalued exchange rate is effectively a tax on all exports. Because the burden is spread among many exporters, and the extent of overvaluation is not obvious, such measures are politically acceptable.

However, there is a limit to the expression of policies in tariff equivalents. Two policies which have the same effect on the difference between domestic and world prices may distort trade to different degrees. Although deficiency payments schemes and export subsidies support producers and lead to a fall in world prices, the effect on domestic consumers is different. Taxpayers fund a deficiency payments scheme, whereas part of the cost of an export subsidy is borne by consumers. Furthermore, domestic prices are effected by assistance to intermediate inputs and value-added factors, such as input subsidies or tax concessions respectively. Decoupled assistance, unrelated to production, has limited trade-distorting effect. (ABARE 1988, p. 54) Hence, care is required in expressing policies in tariff equivalents. Policies that are equivalent at one price level may not be at another.

5.1.6 Periodicity

In static models, the path taken by the endogenous variables in going from one equilibrium to another is not ascertained. Likewise, the time taken is not specified, but is implicitly assumed to be a number of years. In dynamic models, the time period must be explicitly specified. In dealing with an annual crop, a period of one year appears most appropriate. This is also compatible with parameter estimates, which are based on annual data. Short run elasticities are used in the dynamic models, in which some link between periods is postulated.

5.1.7 Product homogeneity

In the empirical analysis, wheat is treated as an homogeneous product. At issue is the substitutability at the margin of various classes of wheat. The Australian Wheat Board has four major classes, the USA five. About three quarters of Australian wheat is Australian Standard White (ASW), whereas about half of the US wheat is hard red winter. The correlation between the US average farm price for wheat and the cash price for hard red winter wheat at Kansas from 1970 to 1983 is 0.99. (Sniekers and Wong 1987, p. 38). Furthermore, ASW is similar to hard red winter wheat in terms of end use and protein characteristics. Sniekers and Wong use a transfer function model to show that there is a significant relationship between US and Australian prices, with US prices setting the lead.

5.1.8 Cross-commodity effects

Wheat is somewhat substitutable in consumption with other grains, and on the supply side, with other agricultural products. Furthermore, a difficulty in analysing retaliation in practice is the possibility that if a country imposes a tariff on one commodity, other countries may retaliate by imposing tariffs on other commodities. This is clearly the case in some instances. However, retaliation has tended to occur in the same market. It is assumed that the cross-commodity effects, due to both retaliation and substitution, are insignificant.

5.1.9 Stockholding

Throughout most of this analysis stocks are assumed to remain unchanged[5]. In this model, this is similar to assuming that stocks are zero. The modelling of stock changes in the dynamic model requires inequality constraints whereas the dynamic programming solution technique used for much of the analysis requires equalities. However, in a deterministic model, there are no supply and demand fluctuations to even out, and therefore the bias introduced by assuming unchanging stock levels may not be as great as it at first appears.

5.2 A Linear Trade Model

In this section, it is assumed that within each country, producer and consumer prices are the same. This assumption will be relaxed later.

Consider an homogeneous product traded between n countries with linear demand and supply curves

$$D_i = \alpha_i - \beta_i P_i, \tag{5.1}$$

$$S_i = \gamma_i + \delta_i P_i, \tag{5.2}$$

where D_i and S_i denote quantities demanded and supplied in country i; P_i denotes the

[5]This assumption is relaxed in Chapter 8.

current price paid by consumers and received by producers; and α_i, β_i, γ_i and δ_i refer to the usual intercept and slope parameters, which are all non-negative.

Assuming no change in stocks, and therefore market clearance

$$\Sigma_i^n(D_i - S_i) = 0. \tag{5.3}$$

The market clearing free trade price is

$$P^f = \frac{\Sigma_i^n(\alpha_i - \gamma_i)}{BD}, \tag{5.4}$$

where

$$BD = \Sigma_i^n(\beta_i + \delta_i). \tag{5.5}$$

With the introduction of a tariff x_i the market clearing tariff-ridden world price becomes

$$P^w = \frac{\Sigma_i^n(\alpha_i - \gamma_i - (\beta_i + \delta_i)x_i)}{BD}, \tag{5.6}$$

where

$$x_i = P_i - P^w. \tag{5.7}$$

With linear schedules, the total welfare function[6] to be maximized for country i is

$$W_i = CS_i + PS_i + TR_i, \tag{5.8}$$

with

$$CS_i = \frac{D_i^2}{2\beta_i}, \tag{5.9}$$

$$PS_i = \frac{S_i^2 - \gamma_i^2}{2\delta_i}, \tag{5.10}$$

$$TR_i = x_i(D_i - S_i). \tag{5.11}$$

CS_i, PS_i and TR_i refer to consumer surplus, producer surplus[7], and tariff revenue respectively. D_i and S_i now depend on x_j for all j.

[6] A derivation of the consumer and producer surplus measures is contained in Appendix C.

[7] Equation (5.10) for PS_i assumes γ exceeds zero, as is the case for all data used here. If γ is negative, $PS_i = S_i^2/2\delta_i$. The difference, $-\gamma_i^2/2\delta_i$, is a constant which drops out upon differentiation.

The importer's optimum tariff is that rate which maximises the country's economic welfare. This can be found by differentiating W_i with respect to x_i, and setting the derivative equal to zero. A derivation is presented in Appendix D. The general formula, for each of n countries, is as follows

$$x_i^* = \frac{(1 - R_i)V_i}{R_i(2 - R_i)(\beta_i + \delta_i)} \tag{5.12}$$

where

$$R_i = \frac{\Sigma_{j \neq i}(\beta_j + \delta_j)}{\Sigma_{i=1}^{n}(\beta_i + \delta_i)} \tag{5.13}$$

$$V_i = D_i\{P\} - S_i\{P\}. \tag{5.14}$$

V_i is thus the trade flow that would hold if x_i were zero.

5.2.1 Cournot-Nash algorithm

Equation (5.12) provides a means of finding each country's optimal tariff without retaliation. However, as retaliation does occur, it is necessary to take into account how each country's tariff affects the optimal tariff of every other country. One approach to this problem is to solve a simultaneous set of equations[8]. This can be done by solving

$$x = H^{-1}k \tag{5.15}$$

where x is a vector of optimum tariffs, k is a vector of constants, equal to the optimum tariff without retaliation, as given by equation (5.12), and H is an nxn matrix of partial derivatives, such that

$$\begin{aligned} H_{ij} &= \frac{-G_i(\beta_i + \delta_i)(\beta_j + \delta_j)}{\Sigma(\beta_j + \delta_j)} \quad for\ i \neq j \\ &= 1 \quad for\ i = j. \end{aligned} \tag{5.16}$$

[8]Two other approaches were developed. One involves an iterative analytic technique, the other an iterative quadratic programming solution. Details are provided in Appendix F.

where

$$G_i = \frac{1 - R_i}{R_i(2 - R_i)(\beta_i + \delta_i)} \tag{5.17}$$

The derivation of H_{ij} is shown in Appendix E.

This technique is computationally efficient as it requires only one matrix inversion to obtain the equilibrium solution.

5.2.2 Stackelberg solution

The stackelberg solution is obtained as follows. First, each follower's optimal response is calculated for any given tariff set by the leader. The leader's welfare is then computed. By searching over a range of tariffs, the leader's welfare-maximising tariff can be found.

There are a variety of search procedures available that do not require continuity or differentiability of the function being optimised. The most efficient one dimensional sequential search method is based on Fibonacci numbers, and requires only that the function be concave to ensure that a global optimum is obtained. (See Cooper and Steinberg (1970) for a discussion of this and alternative search procedures.) By choosing successive points for evaluation of the function according to Fibonacci's infinite number series, the optimum can be guaranteed to be found to any degree of accuracy with the minimum number of evaluations.

5.2.3 Welfare weights

One approach to the estimation of welfare weights was developed by Rausser and Freebairn (1974). They showed how weights can be deduced from the chosen (observed) policies, given that the policymakers are maximising their weighted welfare (or policy preference) function.

Sarris and Freebairn (1983) use a revealed preference approach to determine weights applicable to the world wheat trade. Using a linear model, they derive expressions for domestic supply and demand prices which include weights (equations (9) and (10), p. 216). Equations for the weights as a function of supply and demand parameters and observed prices are then derived. However, the estimated weights are not consistent with a Cournot solution. In spite of finite elasticities, their model yields a free trade policy if weights are equal. This implicitly assumes that all countries are small, in the sense of having no impact on the world price.

Tyers (1986) generalises the approach of Sarris and Freebairn to multiple, interactive commodity markets. He firstly derives the conditions for optimum nominal protection rates (p. 13) and then estimate weights by solving the 'inverse optimum' problem, taking the protection rates as given (observed). In setting their policies, each country assumes that its rivals will not respond. The estimation procedure is somewhat cumbersome, due to the interaction between the sizeable number of commodities involved, and the treatment of some commodities as inputs into the production of others. Therefore, the system of equations for estimating the weights is solved numerically.

The approach used here is similar in some respects to that of Tyers, in that it derives from Sarris and Freebairn's approach, and utilises the 'inverse optimum' theorem. However, neither Sarris and Freebairn nor Tyers calculate weights from a Cournot-Nash equilibrium.

Initially, domestic prices are restricted to one level. This implies that sufficient degrees of freedom are available for the estimation of only two welfare weights. For present purposes, it is useful to constrain the weights on consumers' and taxpayers' welfare to one value. If the weight on producers' welfare can be denoted w_{pi}, than the weight on both consumers' and taxpayers' welfare is $(3 - w_{pi})/2$ (assuming weights average unity). The optimal tariff with these welfare weights is then

$$x_i^{*} = \frac{A_i + w_{pi}B_i}{C_i - w_{pi}D_i} \tag{5.18}$$

where

$$A_i = 1.5((1 - R_i)(\alpha_i - \beta_i P) - (\gamma_i + \delta_i P)) \tag{5.19}$$

$$B_i = .5((R_i - 1)((\alpha_i - \beta_i P) + (2R_i + 1)(\gamma_i + \delta_i P)) \tag{5.20}$$

$$C_i = 1.5(-R_i\beta_i + 2R_i(\beta_i + \delta_i)) \tag{5.21}$$

$$D_i = -(R_i^2\delta_i - .5R_i^2\beta_i + R_i(\beta_i + \delta_i)) \tag{5.22}$$

Equation (5.18) is the weighted equivalent of equation (5.12).

To estimate the weights, an expression for w_{pi} can be derived from equation (5.18)

$$w_{pi} = \frac{x_i C_i - A_i}{B_i + x_i D_i}. \tag{5.23}$$

It follows that if the observed tariff x_i is equal to the optimum tariff, then w_{pi} will equal unity (as will w_{ci} and w_{gi}). If $x_i \geq x_i^*$, then $w_{pi} \geq 1$, and vice versa. In contrast to Sarris and Freebairn's results, w_{pi} can exceed 1 even though domestic prices are equated with world prices. This will be so if the optimum policy is an export tax. Likewise, for importers with market power, $w_{pi} \leq 1$ if a free trade policy is maintained.

Welfare weights show the marginal cost per dollar transferred. A weight of 1.05 for example suggests that society values that unit at \$1.05 for every \$1.00 transferred. The marginal deadweight loss is 5 cents. This is what Gardner (1983) refers to as the 'price of redistribution' (p. 227).

Once estimated, the welfare weights provide a measure of the relative strengths of the various groups in the policy making process. This can be used as a basis for comparisons over time, perhaps to measure the extent to which particular groups have gained favour with policymakers over a period. Similarly, the weights can be used in spatial comparisons, to indicate for example the degree to which producers are favoured in producing, exporting or developing countries. A more important use is to assess how regions or countries are likely to respond to policy or other changes made by their rivals. Responses to various policy changes are likely to be influenced by the weights attached to the welfare function. An example of such an application can be found in Tyers (1986). The validity of welfare weights for policy analysis is of course based on the notion that the weights are relatively stable over time. Care must be taken to ensure that the weights are derived from representative years, rather than years in which the outcomes may be unintended, due to factors beyond the policymakers control.

5.3 The World Wheat Market: One Domestic Price

The analysis developed here can suitably be applied to the international wheat market. A detailed description of the market can be found in Chapter 3. The potential for market power exists on the supply side because of the significant concentration. One producer, the United States, supplies up to half of the international trade. The five major exporters supply around 95 per cent of the trade. There is also some scope for market power amongst buyers, although evidence of this is less convincing. The market structure provides an opportunity for tariffs and taxes. Government intervention gives the many individual producers an opportunity to capture some of the monopoly rents. Consumers and taxpayers are also affected by government trade policies.

However, in practice government involvement goes further than just imposing the optimal tariff or export tax. Policies take a variety of forms, and are invariably aimed at maintaining and stabilising domestic prices, Each policy can be evaluated in terms of its effect on the domestic price. The observed policies are used here to indicate government preferences, which in turn are used as a basis for determining how each country might react in a trade war.

A further feature of the wheat trade is the inability of those benefitting from free trade to impose a cooperative welfare maximising outcome. In contrast to other sectors, cooperation in agriculture is conspicuously absent.

5.3.1 The data

The data used here are the same as that used by Sarris and Freebairn (1983, p. 220), and are shown in Table 5.1. The twenty one regions are similar to those of the USDA's grain-oilseeds-livestock model (Rojko et al. 1978). The price and quantity data refer to an average of 1978-79 and 1979-80. Some of the elasticities are from the GOL model; others are obtained from later studies. The USSR, China, Eastern Europe and the Rest-of-World are treated as net trading entities. An excess demand curve is specified for these regions. The world price is the US Gulf hard red winter wheat price. Aggregated regions are treated as internally unified tariff setting entities. The use of this data also enables comparison with Sarris and Freebairn's results.

5.3.2 Import tariff wars

The supply and demand intercept and slope parameters can be derived directly from the data[9]. It is straight forward to compute the free trade solution, in which parameters remain unchanged, and no country sets a tax. Table 5.2 shows the trade flows for the three alternative solutions (free trade, Cournot-Nash and Stackelberg). Welfare levels are shown in the free trade case, and the optimum tariff and the percentage change in welfare are given in the remaining cases.

In the free trade case, world prices are \$176 compared with the base price level of \$158/t. Total trade volume is 65.8 mmt, lower than the 68.2 mmt observed in the base period. Notably, under free trade the EC would have a balanced trade as opposed to being a net exporter. These results are (as expected) similar to those obtained by Sarris and Freebairn.

For the Cournot-Nash and Stackelberg cases, Table 5.2 shows the percentage change in trade and welfare in comparison to the free trade version. The tariff levels are also given. Negative tariffs reflect a domestic price below the world price (export taxes or import subsidies).

In the Cournot-Nash case, world price falls to \$172/t, but domestic prices are higher as tariffs of up to \$22/t are imposed. Total trade has diminished marginally, as has welfare (from the free trade level of \$172257m to \$172248m). The entire welfare loss is borne by exporters, and this is not matched by the increase in importers' welfare. This provides the expected result that although each importer has acted optimally, the world as a whole is worse off due to the imposition of nationally optimal policies.

It is apparent from these results that large changes in tariffs lead to quite small changes in welfare. One reason for this is the large number of countries in the model; none of

[9]This is shown in Appendix B.

Table 5.1: Base Simulation Data 1978-79 To 1979-80

Region	S (mmt)	D (mmt)	D - S (mmt)	P^d (US$/t)	P^s (US$/t)	Es	Ed
United States	53.25	22.40	-30.85	158	158	0.20	0.15
Canada	19.45	5.15	-14.30	158	158	0.17	0.10
Australia	17.18	3.00	-14.18	175	158	0.10	0.10
Argentina	7.95	4.35	-3.60	123	123	0.12	0.05
South Africa	1.95	1.70	-0.25	175	158	0.12	0.07
EC	46.30	41.25	-5.05	221	221	0.35	0.20
Other Western Europe	10.15	10.30	0.15	221	221	0.35	0.20
Japan	0.45	6.15	5.70	200	743	0.10	0.22
Eastern Europe			4.15	158	158		0.10
USSR			7.55	158	158		0.15
China			7.40	158	158		0.25
Brazil	2.60	6.70	4.10	150	211	0.15	0.12
Central America & Other South America	3.75	9.85	6.10	170	170	0.15	0.17
Egypt	1.90	6.96	5.06	120	120	0.12	0.17
Other North Africa & Middle East	25.60	35.39	9.79	200	200	0.04	0.12
Other Africa	0.75	3.50	2.75	175	175	0.15	0.25
India	33.37	35.14	1.77	158	158	0.10	0.20
Other South Asia	12.63	15.86	3.23	124	124	0.10	0.20
South East Asia	0.10	1.40	1.30	150	150	0.10	0.10
East Asia		5.10	5.10	158	158		0.15
Rest of World			4.05	158	158		0.25

Source: Sarris and Freebairn, 1983.

S denotes production; D - consumption; D - S - net imports; P^s- producer price; P^d - consumer price; Es - supply elasticity; Ed - demand elasticity.

Table 5.2: Trade Volume, Welfare and Tariffs for the Free Trade, Cournot-Nash and Stackelberg Solutions

	Free Trade		Cournot-Nash			Stackelberg†		
Region	Trade (mmt)	Welfare ($m)	Trade (% chg)	Tariff ($/t)	Welfare (% chg)	Trade (% chg)	Tariff ($/t)	Welfare (% chg)
United States	-32.4	19934	-1.06	0.00	-0.63	-0.98	0.00	-0.58
Canada	-14.7	7145	-0.64	0.00	-0.80	-0.59	0.00	-0.74
Australia	-14.4	5508	-0.34	0.00	-1.01	-0.31	0.00	-0.93
Argentina	-4.1	6472	-0.90	0.00	-0.24	-0.83	0.00	-0.22
South Africa	-0.2	2629	-4.07	0.00	-0.03	-3.76	0.00	-0.03
EC	0.0	31109	3974.95	0.91	0.00	4719.16	0.06	0.00
Other Western Europe	1.3	7574	1.84	2.93	0.07	1.64	2.74	0.06
Japan	5.9	3019	-0.99	12.40	0.74	-1.63	13.62	0.68
Eastern Europe	4.1	3206	-0.30	8.61	0.49	-0.32	8.60	0.46
USSR	7.4	3844	-1.13	15.60	0.73	-1.15	15.54	0.67
China	7.2	2209	-1.84	15.15	1.20	-1.87	15.07	1.11
Brazil	4.0	4434	-0.83	8.49	0.35	-0.87	8.43	0.32
Central America & Other South America	6.0	5476	-1.93	12.71	0.41	-1.97	12.62	0.37
Egypt	4.4	2407	-1.45	9.32	0.69	-1.51	9.23	0.64
Other North Africa & Middle East	10.4	34561.	-4.62	21.99	0.10	-4.66	21.85	0.09
Other Africa	2.7	1344	-0.39	5.79	0.79	-0.45	5.75	0.73
India	0.6	18897	21.73	1.82	0.01	23.72	1.34	0.01
Other South Asia	1.4	6283	1.75	3.19	0.09	1.67	2.93	0.08
South East Asia	1.3	1036	0.09	2.68	0.48	0.07	2.67	0.44
East Asia	5.0	3951	-0.43	10.59	0.49	-0.45	10.56	0.45
Rest of World	4.0	1219	-0.73	8.35	1.25	-0.77	8.31	1.15

Trade and welfare percentage changes are from free trade levels.

EC imports increased from a low base of .01 to .40.

†Japan is the leader in this Stackelberg solution.

them possess much market power. For many importers, the volume imported is quite small compared with consumption and production. The consumer and producer surpluses dominate the deadweight losses.

In the Stackelberg case, Japan is the leader, in the first instance. (Carter and Schmitz (1979) using data up to 1976-77, suggest that Japan may have been acting as a price leader in exercising its buying power as an importer.) The Stackelberg solution results in similar conclusions to the Cournot-Nash. Prices, trade volume and global welfare fall in comparison to the free trade solution. Japan, with perfect foresight into its rivals reactions, chooses an optimum tariff of \$13.62/t, marginally higher than in the Cournot-Nash solution. If there had in fact been no retaliation, Japan would have optimised its welfare with a tariff of \$12.35/t, fractionally below the Cournot-Nash tariff of \$12.40/t. Retaliation has the effect of lowering Japan's welfare, and it responds by raising its tariff even further.

World price is similar, at \$172/t. Japanese taxpayers gain at the expense of Japanese consumers, but welfare and trade flows for the rest of the world are practically unchanged from the Cournot-Nash solution. This is due no doubt to relatively small size of Japan in the world wheat market.

Similar results hold if countries or regions other than Japan are assumed to act noncooperatively as Stackelberg leaders. In comparison to free trade, world prices, trade volume and global welfare fall. The optimum tariff for each leader is higher than the Cournot-Nash levels. The optimal tariff without retaliation is below both the Cournot-Nash and Stackelberg levels. This is shown in Table 5.3. Retaliation thus escalates the tariff war. However, the difference between the no-retaliation results and either of the other two solutions is surprisingly small. Once an optimum tariff is in place, other countries can do little to influence it. This is because tariff changes effect the world price by a comparatively small amount, depending on the ratio of relative elasticities, R_i. Any one country has little effect on the world price, and hence little effect on the optimal tariffs of the other traders.

Up to this point, it has been assumed that exporters have followed a free trade policy, by neither imposing an optimum export tax, nor by subsidising their exports. This

Table 5.3: Optimum Tariffs Under Alternative Retaliatory Assumptions

	No Retaliation ($/t)	Cournot-Nash ($/t	Stackelberg ($/t)
Japan	12.35	12.40	13.62
USSR	15.54	15.60	17.15
China	15.07	15.15	16.38
Other North Africa & Middle East	21.84	21.99	23.52

assumption will now be relaxed.

5.3.3 Trade wars with export taxes

Table 5.4 shows the impact of export taxes, in addition to tariffs, on trade flows, and welfare, tariff and tax levels. In generating these results, it has been assumed that both exporters and importers apply their optimum policies.

With exporter now setting taxes in addition to the tariffs set by importers, world price is $189/t, while global welfare and trade volume are significantly below both the free trade levels and the Cournot-Nash equilibrium levels derived without taxes. Due to their concentration, exporters are in a better position to exploit market power than importers. This is borne out by the observation that even though all countries have attempted to apply optimum policies, all the importers have suffered a fall in welfare. By contrast, all exporters have gained.

Note also that with the higher world price, the EC and India have switched from importing to exporting. The large percentage change in trade for the EC reflects it initial balanced trade position.

Table 5.4: Cournot-Nash Solution With Export Taxes

Region	Trade (% chg)	Tax† ($/t)	Welfare (% chg)
United States	-15.6	-70.31	1.1
Canada	-3.0	-31.47	2.6
Australia	-1.5	-30.43	3.4
Argentina	1.0	-8.85	0.8
South Africa	13.4	-0.49	0.1
EC	-13692.2	-3.03	0.0
Other Western Europe	-29.7	2.02	-0.2
Japan	-2.9	12.15	-2.6
Eastern Europe	-1.4	8.51	-1.7
USSR	-2.7	15.34	-2.6
China	-4.5	14.73	-4.3
Brazil	-3.8	8.23	-1.2
Central America & Other South America	-5.5	12.24	-1.4
Egypt	-5.9	8.89	-2.4
Other North Africa & Middle East	-8.7	21.04	-0.4
Other Africa	-3.8	5.59	-2.7
India	-134.9	-0.51	-0.0
Other South Asia	-39.1	1.92	-0.2
South East Asia	-1.2	2.64	-1.6
East Asia	-1.5	10.47	-1.7
Rest of World	-3.5	8.12	-4.3

†Negative values refer to export taxes, positive values to tariffs. Trade and welfare percentage changes are from free trade levels.

Table 5.5: Implicit Welfare Weights

Region	Weight (w_p)
United States	1.09
Canada	1.03
Australia	1.02
Argentina	0.98
South Africa	1.01
EC	1.12
Other Western Europe	1.10
Japan	1.28
Brazil	0.97
Central America & Other South America	1.00
Egypt	0.79
Other North Africa & Middle East	1.015
Other Africa	1.05
India	1.00
Other South Asia	0.93
South East Asia	0.93

5.3.4 Welfare weights estimation

Thus far the welfare accruing to consumers, producers or taxpayers has been weighted equally. The welfare weights which reflect the levels of nominal protection existing in the base period are discussed in this subsection.

The welfare weights are shown in Table 5.5. Weights for the net trading entities have not been calculated, and are assumed to be one in further analysis. They are not shown. The weights are based on equation (5.18), which is applied to the data in Table 5.1. The weights indicate that with the exception of Argentina, producers in all exporting countries are favoured by policymakers. Of this group, the EC has the highest weight of 1.12, followed by the United States with 1.09. The high EC values reflect the high prices paid to producers, while the US weight is determined by the absence of an optimum export tax. For example, if the US tax was at its optimum level, \$70, the weight would be 1. Producers are favoured by the absence of the tax, and this is reflected in a weight in excess of unity.

Of the importers, Japan has by far the highest producer weight, with none of the others favouring their farmers to any significant extent. Of the nine less-developed importing regions for which weights are calculated, four have policies which (significantly) favour consumers and taxpayers. The remainder are fairly neutral, with the exception perhaps of Other Africa with a weight of 1.05.

The relatively low value of these weights indicates that small changes in policymakers preferences are consistent with significant policy changes. The domestic EC price in the base period was $221/t compared with a world price of $158/t, yet this is reflected by a weight of 1.12, that being the marginal cost of transferring one unit of welfare to producers. It is clear then that depending upon the elasticities and the market share, a small change in preferences may lead to a large change in the rate of protection.

5.3.5 Implications

A number of implications can be drawn from these results. First, if a trader can affect the world price, then it is optimum to alter the terms of trade by applying an import tariff or an export tax. This may be the case even in the presence of retaliation. However, due to their small size and influence, the results obtained here suggest that wheat importers cannot, acting noncooperatively, gain a great deal.

These results confirm that while taxes and tariffs may be welfare maximising for individual countries, even when retaliation exists, they are not optimal from a global point of view. Global welfare under free trade was found be superior to tariff-ridden welfare levels in every case. However, because losers are not compensated, some countries may prefer the noncooperative trade war outcome to trade liberalisation.

With the importers acting independently, there is little difference between the Cournot-Nash and Stackelberg solutions. Clearly, in the wheat market no one consuming country has sufficient influence to be a market leader. However, when retaliation is expected the optimum response here is to increase rather than reduce tariffs. This is because a trade war on one side of the market escalates initially. If export taxes were included, the optimum response would be to reduce tariffs.

While export taxes are the most potent way of exploiting market power, they are relatively uncommon. By contrast, export subsidies, while seemingly welfare reducing, are increasingly common. This implies, and the welfare weights confirm, that the policymakers preference functions are quite dissimilar from the unweighted welfare functions. In assessing how other countries might react to policy changes or exogenous shocks, these weights can usefully be taken into account. This will be explored in Chapter 7, in which these weights are used in a dynamic model.

5.4 A Two-Price Model

In the previous section[10], a model in which consumers and producers prices were the same in each country was derived. Unfortunately, domestic consumer and producer prices are often observed to be different. Furthermore, by restricting the model to one domestic price, it is possible to estimate welfare weights for only two groups. In this section a model in which the prices differ is derived. Weights are estimated for three groups, with consumers and taxpayers treated separately, on the assumption that prices reflect a Cournot-Nash equilibrium. Sarris and Freebairn (1983) attempted to do this. In their model each trader assumes that any pricing policy which it implements, such as the imposition of a tariff, will not affect the world price. This 'small country' assumption is inconsistent with the usual understanding of a Cournot equilibrium. Here, Sarris and Freebairn's model is reformulated to account for the impact of policies on the world price.

In contrast to the traditional model, Sarris and Freebairn derive their solution on the simplifying assumption that '*...every trading country takes [the world price] as given. ...[This] implies that each country is concerned with domestic objectives and is not concerned with other countries' reactions to its policies. In other words, we posit a Cournot oligopoly problem.*' (p. 215). In fact they posit zero conjectural variations (that is, each trader conjectures that its rivals will not vary their policies) as in a Cournot model, but assume no effect on world prices. This latter assumption is not consistent with a Cournot model.

[10] Much of the material in this section was published in Vanzetti and Kennedy (1988b). A copy of the published work is reproduced in Appendix I.

Sarris and Freebairn are led to conclude that with equal weights on all components of the welfare function, '*...the optimal policy for the country is a free-trade one.*' (p. 216). This conclusion is consistent with the simplifying small country assumption. After dropping this assumption, the calculations presented here show that the optimal policies are non-zero even if weights are equal.

5.4.1 Derivation of two-price model

Consider the same model as presented previously, except that the demand and supply curves are functions of different prices

$$D_i = \alpha_i - \beta_i P_i^d \tag{5.24}$$

$$S_i = \gamma_i + \delta_i P_i^s \tag{5.25}$$

where P_i^d and P_i^s denote the current price paid by consumers and received by producers in country i respectively; and the other variables are as defined. To keep the algebra to a minimum, there are no additive disturbance terms in (5.24) and (5.25), unlike the demand and supply equations specified by Sarris and Freebairn. It is argued later that this does not lead to a bias in the estimates of expected tariffs or welfare weights. Assuming no change in stocks, and therefore market clearance

$$\Sigma_i^n(D_i - S_i) = 0. \tag{5.26}$$

The market clearing free trade price is

$$P^f = \frac{\Sigma_i^n(\alpha_i - \gamma_i)}{\Sigma_i^n(\beta_i + \delta_i)}. \tag{5.27}$$

The introduction of differential prices for domestic producers (P^s) and consumers (P^d) separates domestic and international prices. The market clearing tariff-ridden world price is now

$$P^w = \frac{\Sigma_i^n(\alpha_i - \gamma_i) - \Sigma_i^n(\beta_i x_i^d - \delta_i x_i^s)}{\Sigma_i^n(\beta_i + \delta_i)} \tag{5.28}$$

where

$$x_i^d = P_i^d - P^w \tag{5.29}$$

$$x_i^s = P^w - P_i^s. \tag{5.30}$$

With linear schedules, and the inclusion of the welfare weights, the total welfare function to be maximized for country i is

$$W_i = w_{ci}CS_i + w_{pi}PS_i + w_{gi}TR_i \tag{5.31}$$

with

$$\begin{aligned} CS_i &= \frac{D_i^2}{2\beta_i} && (5.32)\\ PS_i &= \frac{S_i^2 - \gamma_i^2}{2\delta_i} && (5.33)\\ TR_i &= x_i^d D_i + x_i^s S_i. && (5.34) \end{aligned}$$

CS_i, PS_i and TR_i refer to consumer surplus, producer surplus and tariff revenue respectively. Tariff revenue is now composed of two terms, reflecting the two domestic prices. The ws are the appropriate weights. D_i and S_i now depend on x_j^d and x_j^s for all j.

Setting the partial derivatives of W_i with respect to x_i^d and x_i^s equal to zero, for an interior solution, gives

$$\begin{aligned} \partial W_i/\partial x_i^d &= \frac{w_{ci}V_{3i}}{\beta_i}[\alpha_i - \beta_i P^f + x_i^d V_{3i} + \beta_i \frac{\Sigma_{j\neq i}\beta_j x_j^d}{BD} + x_i^s V_{1i} - \beta_i \frac{\Sigma_{j\neq i}\delta_j x_j^s}{BD}]\\ &+ \frac{w_{pi}V_{1i}}{\delta_i}[\gamma_i + \delta_i P^f + x_i^d V_{1i} - \delta_i \frac{\Sigma_{j\neq i}\beta_j x_j^d}{BD} + x_i^s V_{2i} + \delta_i \frac{\Sigma_{j\neq i}\delta_j x_j^s}{BD}]\\ &+ w_{gi}[\alpha_i - \beta_i P^f + 2x_i^d V_{3i} + \beta_i \frac{\Sigma_{j\neq i}\beta_j x_j^d}{BD} + 2x_i^s V_{1i} - \beta_i \frac{\Sigma_{j\neq i}\delta_j x_j^s}{BD}]\\ &= 0 && (5.35) \end{aligned}$$

$$\begin{aligned} \partial W_i/\partial x_i^s &= \frac{w_{ci}V_{1i}}{\beta_i}[\alpha_i - \beta_i P^f + x_i^d V_{3i} + \beta_i \frac{\Sigma_{j\neq i}\beta_j x_j^d}{BD} + x_i^s V_{1i} - \beta_i \frac{\Sigma_{j\neq i}\delta_j x_j^s}{BD}]\\ &+ \frac{w_{pi}V_{2i}}{\delta_i}[\gamma_i + \delta_i P^f + x_i^d V_{1i} - \delta_i \frac{\Sigma_{j\neq i}\beta_j x_j^d}{BD} + x_i^s V_{2i} + \delta_i \frac{\Sigma_{j\neq i}\delta_j x_j^s}{BD}]\\ &+ w_{gi}[\gamma_i + \delta_i P^f + 2x_i^d V_{1i} - \delta_i \frac{\Sigma_{j\neq i}\beta_j x_j^d}{BD} + 2x_i^s V_{2i} + \delta_i \frac{\Sigma_{j\neq i}\delta_j x_j^s}{BD}]\\ &= 0 && (5.36) \end{aligned}$$

where $BD = \Sigma_j^n(\beta_j + \delta_j)$, and

$$\begin{array}{lclclcl} V_{1i} & \equiv & \frac{-\beta_i\delta_i}{BD} & = & \frac{\partial D_i}{\partial x_i^s} & = & \frac{\partial S_i}{\partial x_i^d} \\ V_{2i} & \equiv & \frac{\delta_i^2}{BD} - \delta_i & = & \frac{\partial S_i}{\partial x_i^s} & & \\ V_{3i} & \equiv & \frac{\beta_i^2}{BD} - \beta_i & = & \frac{\partial D_i}{\partial x_i^d}. & & \end{array}$$

These equations hold simultaneously for n countries. After rearrangement, they can be expressed in matrix notation as

$$Ax = g \tag{5.37}$$

where

$$A = \begin{bmatrix} a_1 & b_1 & \beta_2 z_1 & -\delta_2 z_1 & \ldots & \beta_n z_1 & -\delta_n z_1 \\ b_1 & c_1 & \beta_2 y_1 & -\delta_2 y_1 & \ldots & \beta_n y_1 & -\delta_n y_1 \\ \beta_1 z_2 & -\delta_1 z_2 & a_2 & b_2 & \ldots & \beta_n z_2 & -\delta_n z_2 \\ \beta_1 y_2 & -\delta_1 y_2 & b_2 & c_2 & \ldots & \beta_n y_2 & -\delta_n y_2 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \beta_1 z_n & -\delta_1 z_n & \beta_2 z_n & -\delta_2 z_n & \ldots & a_n & b_n \\ \beta_1 y_n & -\delta_1 y_n & \beta_2 y_n & -\delta_2 y_n & \ldots & b_n & c_n \end{bmatrix}$$

$$x' = \begin{bmatrix} x_1^d \; x_1^s \; x_2^d \; x_2^s \; \cdots \; x_n^d \; x_n^s \end{bmatrix}$$

$$g' = \begin{bmatrix} g_1^d \; g_1^s \; g_2^d \; g_2^s \; \cdots \; g_n^d \; g_n^s \end{bmatrix}$$

In matrix A

$$a_i = \frac{w_{ci}}{\beta_i}V_{3i}^2 + \frac{w_{pi}}{\delta_i}V_{1i}^2 + 2w_{gi}V_{3i} \tag{5.38}$$

$$b_i = \frac{w_{ci}}{\beta_i}V_{1i}V_{3i} + \frac{w_{pi}}{\delta_i}V_{2i}V_{1i} + 2w_{gi}V_{1i} \tag{5.39}$$

$$c_i = \frac{w_{ci}}{\beta_i}V_{1i}^2 + \frac{w_{pi}}{\delta_i}V_{2i}^2 + 2w_{gi}V_{2i} \tag{5.40}$$

$$z_i = \frac{w_{ci}V_{3i} - w_{pi}V_{1i} + w_{gi}\beta_i}{\Sigma_j^n(\beta_j + \delta_j),} \tag{5.41}$$

$$y_i = \frac{w_{ci}V_{1i} - w_{pi}V_{2i} - w_{gi}\delta_i}{\Sigma_j^n(\beta_j + \delta_j)}. \tag{5.42}$$

In vector g'

$$g_i^d = \frac{-w_{ci}V_{3i}\alpha_i}{\beta_i} - \frac{w_{pi}V_{1i}\gamma_i}{\delta_i} - w_{gi}\alpha_i + P^f(w_{ci}V_{3i} - w_{pi}V_{1i} + w_{gi}\beta_i) \tag{5.43}$$

$$g_i^s = \frac{-w_{ci}V_{1i}\alpha_i}{\beta_i} - \frac{w_{pi}V_{2i}\gamma_i}{\delta_i} - w_{gi}\gamma_i + P^f(w_{ci}V_{1i} - w_{pi}V_{2i} - w_{gi}\delta_i). \tag{5.44}$$

Equation (5.37) can be solved by matrix inversion to provide the Cournot-Nash equilibrium tariffs

$$t = A^{-1}g \tag{5.45}$$

Note that if the intercept terms of the demand and supply equations (α_i and γ_i in (5.24) and (5.25)) were stochastic, equation (5.37) would still solve for expected tariffs if the intercept terms on the right hand side were set at their expected values. This follows because the terms, which appear only in equations (5.43) and (5.44), do not interact. Thus, as in the analysis of Sarris and Freebairn, expected equilibrium tariffs can be determined without taking account of the variances of α_i and γ_i.

Following Sarris and Freebairn, it is assumed that a set of observed tariffs, $\bar{x}$, are Cournot equilibrium tariffs, and weights are normalized by requiring that

$$w_{ci} + w_{pi} + w_{gi} = 3. \tag{5.46}$$

Equations (5.35), (5.36) and (5.46) can be expressed in matrix notation as

$$Hw = f \tag{5.47}$$

where

$$H = \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ 1 & 1 & 1 \end{bmatrix}$$

$$w' = [w_C \; w_p \; w_g]$$

and

$$f' = [0\ 0\ 3].$$

In matrix H

$$\begin{aligned} h_{11} &= \frac{V_{3i}}{\beta_i}[\alpha_i - \beta_i P^f + \bar{t}_i^d V_{3i} + \bar{t}_i^s V_{1i} + \beta_i R_i] && (5.48) \\ h_{12} &= \frac{V_{1i}}{\delta_i}[\gamma_i + \delta_i P^f + \bar{t}_i^d V_{1i} + \bar{t}_i^s V_{2i} - \delta_i R_i] && (5.49) \\ h_{13} &= \alpha_i - \beta_i P^f + 2\bar{t}_i^d X_{3i} + 2\bar{t}_i^s X_{1i} + \beta_i R_i && (5.50) \\ h_{21} &= \frac{X_{1i}}{\beta_i}[\alpha_i - \beta_i P^f + \bar{t}_i^d X_{3i} + \bar{t}_i^s + \beta_i R_i] && (5.51) \\ h_{22} &= \frac{X_{2i}}{\delta_i}[\gamma_i + \delta_i P^f + \bar{t}_i^d X_{1i} + \bar{t}_i^s X_{2i} - \delta_i R_i] && (5.52) \\ h_{23} &= \gamma_i + \delta_i P^f + 2\bar{t}_i^d X_{1i} + 2\bar{t}_i^s X_{2i} - \delta_i R_i, && (5.53) \end{aligned}$$

where

$$R_i = \frac{\Sigma_{j \neq i}(x_j^d \beta_j - x_j^s \delta_j)}{\Sigma_j^n(\beta_j + \delta_j)}. \qquad (5.54)$$

Hence,

$$w = H^{-1} f. \qquad (5.55)$$

5.4.2 Tariff solutions and weights

The models were used to recalculate the results of Sarris and Freebairn. First, tariffs were calculated assuming an equally weighted welfare function ($w_{ci} = w_{pi} = w_{gi} = 1$). They are presented in Table 5.6. With market power taken into account, it is clear that free trade (that is, zero tariffs) is not the optimal policy if weights are equal. However, with equal weights, it is optimal to set P^d and P^s at the same level, eliminating distortions in both consumption and production. While the United States appeared to be conducting an evenhanded policy in the base period (in the sense that producer and consumer prices equaled the world benchmark price) it was in fact favouring producers by not imposing the optimum tax.

Second, as an alternative it was assumed that the tariff structure observed in the base period was the outcome of a Cournot process, and corresponding welfare weights were calculated. The revised results are presented in Table 5.6. The weights, at least for producers, are broadly similar to those calculated from the one-price model, presented in Table 5.5. The consumer and taxpayer weights differ from each other, and in some instances take values either side of unity, as is the case with Australia. The weights calculated here differ from those of Sarris and Freebairn by a greater margin as market power (as reflected by the equilibrium tariffs) increases. Sarris and Freebairn underestimate producer weights in exporting countries, and overestimate them in importing countries.

The results show that Sarris and Freebairn's simplifying assumption of no market power significantly affects the estimates of optimal policies and weights. The method used here to determine the weights will be used in an application in Chapter 7.

5.5 Market Shares Solution

Throughout this thesis, policymakers set trade taxes so as to optimise a welfare function, which may or may not have non-unitary weights. This assumption is open to the criticism that policymakers, in reality, have other objectives in mind. In this section, it is assumed that the policymakers' objective will be to maintain a certain market share, rather than to optimise welfare. This leads to markedly different results, and highlights the importance of correct specification of objectives.

It is difficult to make a case for the maintenance of market share as a rational policy, even for one country. A given market share is consistent with a particular set of welfare weights. However, when there is a change in the underlying parameters, such as overseas supply, then the market share consistent with the chosen weights also changes. Clearly, all countries can't lift their market share simultaneously. Nevertheless, there is some evidence that the regaining and maintenance of market share was a target of some importance for the United States during the 1980s. Miller (1987), in referring to agricultural trade strategy, notes that it is difficult to retreat from an aggressive stance without losing credibility. Furthermore, '... *market shares have now become the political barometer against which credibility of agricultural leadership is measured*' (p. 914). Miller views this problem as

Table 5.6: Cournot-Nash Equilibrium and Observed Tariffs, and Implicit Welfare Weights

Region	x^d	x^s	$\bar{x}^d$	$\bar{x}^s$	w_c	w_p	w_g
	Equilibrium†		Observed			Estimated‡	
	($/t)	($/t)	($/t)	($/t)			
United States	-70.01	70.01	0.00	0.00	0.917	1.091	0.992
	(0.00)	(0.00)			(1.000)	(1.000)	(1.000)
Canada	-31.37	31.37	0.00	0.00	0.976	1.029	0.995
	(0.00)	(0.00)			(1.000)	(1.000)	(1.000)
Australia	-30.33	30.33	17.00	0.00	0.975	1.022	1.003
	(0.00)	(0.00)			(0.993)	(1.003)	(1.003)
Argentina	-8.81	8.81	-35.00	35.00	1.016	0.978	1.005
	(0.00)	(0.00)			(1.021)	(0.972)	(1.007)
EC	-3.03	3.03	63.00	-63.00	0.915	1.102	0.983
	(0.00)	(0.00)			(0.930)	(1.084)	(0.986)
South Africa	-0.64	0.64	17.00	0.00	0.995	1.003	1.002
	(0.00)	(0.00)			(0.995)	(1.002)	(0.989)
Other West. Europe	2.03	-2.03	63.00	-63.00	0.930	1.084	0.986
	(0.00)	(0.00)			(0.930)	(1.084)	(0.986)
Japan	12.12	-12.12	42.00	-585.00	0.953	1.061	0.985
	(0.00)	(0.00)			(0.944)	(1.067)	(0.989)
Brazil	8.21	-8.21	-8.00	-53.00	0.998	1.016	0.985
	(0.00)	(0.00)			(0.992)	(1.023)	(0.986)
Central America &	12.22	-12.22	12.00	-12.00	1.001	0.999	1.000
Other South America	(0.00)	(0.00)			(0.988)	(1.011)	(1.000)
Egypt	8.88	-8.88	-38.00	38.00	1.062	0.945	0.993
	(0.00)	(0.00)			(1.048)	(0.957)	(0.995)
Other North Africa &	21.06	-21.06	42.00	-42.00	0.990	1.007	1.003
Middle East	(0.00)	(0.00)			(0.980)	(1.014)	(1.006)
Other Africa	5.58	-5.58	17.00	-17.00	0.986	1.012	1.002
	(0.00)	(0.00)			(0.979)	(1.018)	(1.003)
India	-0.48	0.48	0.00	0.00	1.005	0.996	0.999
	(0.00)	(0.00)			(1.000)	(1.000)	(1.000)
Other South Asia	1.93	-1.93	-34.00	34.00	1.055	0.956	0.989
	(0.00)	(0.00)			(1.045)	(0.964)	(0.991)
South East Asia	2.63	-2.63	-8.00	8.00	1.007	0.993	1.000
	(0.00)	(0.00)			(1.005)	(0.995)	(1.000)

Results from Sarris and Freebairn are shown in parenthesis.

†These are equilibrium values assuming unitary weights.

‡Weights if observed tariffs were at their Cournot-Nash equilibrium levels.

contributing to what he calls 'the social trap'. This is essentially, in game-theoretic terms, a prisoners' dilemma.

As noted in Chapter 3, USA production peaked in the early 80s, and whereas production was subsequently maintained, exports fell due to a declining world market and an appreciating exchange rate. A high loan rate and high stock release prices led to a build up of stocks. The USA market share declined from 51 per cent in 1981-82 to 28 per cent in 1985-86. The Export Enhancement Program, which provided for the subsidisation of exports, in conjunction with other factors, led to only a very moderate improvement in market share. One explanatory factor is the use of export subsidies by the EEC.

An export subsidy war can be modelled using an extension of the static trade model outlined earlier in the chapter. In contrast to previous games, a market share game is constant-sum. This implies that it is a game of pure conflict. One's gain is the other's loss. There are, however, non-constant welfare losses, which do not feature in the objective function as it is specified here.

In the following subsection, a market share equation is derived, and a solution is estimated. The USA and the EC use export subsidies to improve their market share, while other countries behave competitively.

5.5.1 Derivation of market share equation

Assume one or more exporters are prepared to subsidise exports when market share falls below some benchmark level. To find the subsidy e_i necessary to regain market share, let

$$V_i = \alpha_i - \gamma_i - (\beta_i + \delta_i)P^w \tag{5.56}$$

and

$$S_i = \frac{V_i}{V}, \tag{5.57}$$

where V_i denotes trade volume in country i, S_i is market share and V is total trade volume. An export subsidy,

$$e_i = P_i - P^w \tag{5.58}$$

influences P^w inversely as follows

$$P^w = \frac{\Sigma_i \alpha_i - \Sigma_i \gamma_i - (\beta_i + \delta_i) e_i}{BD} \tag{5.59}$$

Following the imposition of a subsidy e_i by country i, the volume of trade for country j is

$$V_j = \alpha_j - \gamma_j - (\beta_j + \delta_j) P^f + \frac{(\beta_j + \delta_j)(\beta_i + \delta_i) e_i}{BD}, \tag{5.60}$$

where P^f is the free trade world price. For the subsidising country, the optimal trade volume is

$$- V_i^* = \alpha_i - \gamma_i - (\beta_i + \delta_i)(P^w + e_i). \tag{5.61}$$

With a change in sign,

$$\begin{aligned} V_i^* &= \gamma_i - \alpha_i + (\beta_i + \delta)\left(\frac{\Sigma_i \alpha_i - \Sigma_i \gamma_i - (\beta_i + \delta_i) e_i}{BD} + e_i\right) \\ &= \gamma_i - \alpha_i + (\beta_i + \delta_i) P^f - \frac{(\beta_i + \delta_i)^2 e_i}{BD} + (\beta_i + \delta_i) e_i \\ &= \gamma_i - \alpha_i + (\beta_i + \delta_i) P^f - \frac{[e_i(\beta_i + \delta_i)^2 - (\beta_i + \delta_i) BD]}{BD}. \end{aligned} \tag{5.62}$$

As $V_i^* = S_i^* V$, it follows that

$$\begin{aligned} & S_i^*(\Sigma_{j=1}^m (\alpha_j - \gamma_j) - \Sigma_{j=1}^m (\beta_j + \delta_j) P^f) + S_i^* \frac{\Sigma_{j=1}^m (\beta_j + \delta_j)(\beta_i + \delta_i) e_i}{BD} \\ = \; & \gamma_i - \alpha_i + (\beta_i + \delta_i) P^f - \frac{e_i[(\beta_i + \delta_i)^2 - (\beta_i + \delta_i) BD]}{BD}. \end{aligned} \tag{5.63}$$

where m refers to the number of importers. Hence, the subsidy e_i necessary to restore market share S_i is

$$e_i = \frac{\gamma_i - \alpha_i + (\beta_i + \delta_i) P^f - S_i^*(\Sigma_{j=1}^m (\alpha_j - \gamma_j) - \Sigma_{j=1}^m (\beta_j + \delta_j) P^f)}{S_i^* \frac{\Sigma_{j=1}^m (\beta_j + \delta_j)(\beta_i + \delta_i)}{BD} + \frac{(\beta_i + \delta_i)^2 - (\beta_i + \delta_i) BD}{BD}}. \tag{5.64}$$

Imagine a situation represented by the base period data in Table 5.1, in which the USA has a 49 per cent share of the market, and the EC virtually none. Suppose an exogenous shift in supply occurs in the non-subsidising export countries, perhaps due to a technological improvement. An increase in the supply intercept of 20 per cent in these

Table 5.7: Export Subsidy War

Region	Price ($/t)	Share (%)	Trade (mmt)	Welfare (% change)
United States	238	0.49	-38	-7.6
EC	175	0.00	0	-0.2
Canada	127	0.22	-17	-7.4
Australia	127	0.22	-17	-9.4
Argentina	127	0.07	-5	-2.5
South Africa	127	0.01	-1	-0.7

USA and EC subside exports following a 1.7 per cent production increase in non-subsidising export countries.
Global welfare: Free trade (post-shock) = $172230m, Postwar = $171798m.

countries leads to a world production increase of 1.7 per cent. With no subsidies, world trade increases from 65 mmt to 72 mmt, and the USA share falls from 0.49 to 0.43. Suppose the USA wishes to raise its share back to 0.49, and the EC wants to regain self-sufficiency. Assume the USA applies a subsidy and regains its market share to the target level of 49 per cent. This involves a subsidy of $105, which causes world price to fall to $139 from the free trade post-shock price of $158. Subsidies have precisely the opposite effect of an export tax. If the EC now applies a subsidy in turn, it will bring its trade into balance, but the USA share will now have fallen. A competitive export subsidy war ensues. An iterative process is used to compute the resulting equilibrium, which is given in Table 5.7. Data for importers is not shown. The negative trade values refer to exports.

At completion of the subsidy war, subsidies have risen to $111 and $48, and the world price has fallen to $127[11]. Note that the use of export subsidies results in the target market share being recaptured, and trade volume has increased for the subsidising countries. However, welfare has fallen significantly for most exporters. The EC does not suffer a substantial loss, because of its small trade share. As a result of the trade war, non-subsidising exporters are worse off. Welfare has fallen even below the pre-shock level, in spite of the benefits of the positive supply shift. All importers are better off than previously. However, global welfare has fallen. This is precisely the result one would

[11]Had the EC played first in this game, it would have applied a subsidy of $21, to which the USA would have responded with a subsidy of $86. The final outcome would be the same. The solution is not path dependent.

expect. Of interest here is the extent of the subsidy necessary to regain a comparatively small amount of market share. The subsidy of about $111 is not unrealistic, considering that the subsidies are not targeted in this analysis.

Had Canada rather than the EC being challenging the USA for market share, the USA's subsidy would have been $122, compared with Canada's $169. World price would have fallen to $121. Welfare losses and transfers (to importers) would have been even greater than those resulting from the USA-EC export subsidy war. In the 1980s, the changes in market share have been much greater than the small changes suggested here.

Chapter 6

Conjectural Variations

Thus far the Cournot-Nash solution has been derived and estimated for models with one and two domestic prices, and a Stackelberg solution was found for a one-price model. As noted in Chapter 3, and also by Sarris and Freebairn (1988) in their reply to Vanzetti and Kennedy (1988b), one of the disadvantages of the Cournot-Nash approach is that each trader assumes that rivals will not respond. How will the trade war outcome differ if this assumption is relaxed? Of particular interest is the impact of conjectural variations on optimum policies - the direction and extent to which tariffs change when expectations of retaliation change.

To assess the impact of various conjectures, the same linear trade model is used once again [1]. First, a free trade solution, assuming zero tariffs, is calculated to provide a benchmark for later comparisons. Next a Cournot-Nash solution, assuming zero conjectural variations, is shown. From the observed tariff structure, conjectural variation estimates are obtained through the use of the inverse optimum theorem. Once estimated, these are used to derive optimum tariffs following an exogenous exchange rate change. This conjectural variations equilibrium is then compared with the corresponding (post-depreciation) Cournot-Nash equilibrium. A summary of the results is presented in Table 6.5. The analysis is applied to the same data except that long-run rather than short-run elasticities are

[1] Some of the material in this chapter appeared in Vanzetti and Kennedy (1988c).

used and therefore the results are not directly comparable to those presented in Chapter 5. Because the demand and supply slopes are not as great, the optimum tariffs and welfare levels are reduced.

6.1 Derivation of the Non-Zero Conjectural Variations Model

Once again, consider the same model as that presented in Chapter 5, except that

$$x_i^d = P_i^d - P^w, \tag{6.1}$$

$$x_i^s = P_i^s - P^w. \tag{6.2}$$

Note that now x_i^s is defined as the negative of its previous value. This changes the signs in some of the terms in the equations that follow. This will make the analysis a little easier to understand.

The total welfare function is unchanged, except for the change of sign in the tariff revenue term

$$TR_i = x_i^d D_i - x_i^s S_i. \tag{6.3}$$

The welfare equation is as before

$$W_i = CS_i + PS_i + TR_i. \tag{6.4}$$

The essence of the conjectural variations model is that each trader has expectations as to how rival traders will respond. Due allowance for the response is made when deriving the first order conditions. The Cournot-Nash equilibrium is a special case of the conjectural variations model, and therefore can also be derived from the following equations. The first order conditions are obtained by differentiating the welfare function with respect to the tariffs. The partial derivatives are then equated to zero, for an interior solution, and solved for the optimal tariff.

$$
\begin{aligned}
\partial W_i/\partial x_i^d &= \frac{2D_i}{2\beta_i}\frac{\partial D_i}{\partial x_i^d} + \frac{2S_i}{2\delta_i}\frac{\partial S_i}{\partial x_i^d} + D_i + x_i^d\frac{\partial D_i}{\partial x_i^d} - x_i^s\frac{\partial S_i}{\partial x_i^d}, \\
&= D_i(F_i - 1) + S_i(-F_i) + D_i + x_i^d(F_i\beta_i - \beta_i) - x_i^s(-\delta_i F_i), \\
&= F_i(D_i - S_i + x_i^d\beta_i + x_i^s\delta_i) - x_i^d\beta_i, \qquad (6.5)
\end{aligned}
$$

where

$$
\begin{aligned}
F_i &= (\beta_i + \Sigma_{j\neq i}(\beta_j Z_{ji}^{dd} + \delta_j Z_{ji}^{sd}))/BD, \\
Z_{ji}^{dd} &= \frac{\partial x_j^d}{\partial x_i^d}, \\
Z_{ji}^{sd} &= \frac{\partial x_j^s}{\partial x_i^d}.
\end{aligned}
$$

From equations (6.1), (6.2), (6.4), (6.5) and (6.6) of Chapter 5 and (7.1) and (7.2) of this chapter, it follows that

$$
\begin{aligned}
D_i - S_i &= \alpha_i - \gamma_i - (\beta_i + \delta_i)P^f + x_i^d\beta_i e_i + x_i^s\delta_i e_i \\
&\quad + e_i\Sigma_{j\neq i}(\beta_j x_j^d + \delta_j x_j^s) - \beta_i x_i^d - \delta_i x_i^s, \qquad (6.6)
\end{aligned}
$$

where e_i is redefined to be

$$
e_i = (\beta_i + \delta_i)/BD,
$$

Equation (7.5) can now be rewritten as

$$
\partial W_i/\partial x_i^d = F_i(\alpha_i - \gamma_i - (\beta_i + \delta_i)P^f + e_i\Sigma_{j=1}^n(x_i^d\beta_j + \delta_j x_j^s)) - x_i^d\beta_i \qquad (6.7)
$$

Likewise, W_i can be differentiated with respect to x_i^s to obtain

$$
\begin{aligned}
\partial W_i/\partial x_i^s &= \frac{2D_i}{2\beta_i}\frac{\partial D_i}{\partial x_i^s} + \frac{2S_i}{2\delta_i}\frac{\partial S_i}{\partial x_i^s} + x_i^d\frac{\partial D_i}{\partial x_i^s} - S_i - x_i^s\frac{\partial S_i}{\partial x_i^s} \\
&= G_i(\alpha_i - \gamma_i - (\beta_i + \delta_i)P^f + e_i\Sigma_{j=1}^n(x_i^d\beta_j + \delta_j x_j^s)) - x_i^s\delta_i \qquad (6.8)
\end{aligned}
$$

where

$$
\begin{aligned}
G_i &= (\delta_i + \Sigma_{j\neq i}(\beta_j Z_{ji}^{dd} + \delta_j Z_{ji}^{sd}))/BD, \\
Z_{ji}^{ds} &= \frac{\partial x_j^d}{\partial x_i^s}, \\
Z_{ji}^{ss} &= \frac{\partial x_j^s}{\partial x_i^s}.
\end{aligned}
$$

Setting the partial derivatives of W_i with respect to x_i^d and x_i^s equal to zero, and solving gives

$$x_i^d = \frac{-F_i(\alpha_i - \gamma_i - (\beta+\delta)P^f + e_i\delta_i x_i^s + e_i\Sigma_{j\neq i}(\beta_j x_j^d + \delta_j x_j^s))}{F_i e_i \beta_i - \beta_i}, \tag{6.9}$$

$$x_i^s = \frac{-G_i(\alpha_i - \gamma_i - (\beta+\delta)P^f + e_i\beta_i x_i^d + e_i\Sigma_{j\neq i}(\beta_j x_j^d + \delta_j x_j^s))}{G_i e_i \delta_i - \delta_i}. \tag{6.10}$$

These equations hold simultaneously for n countries. After rearrangement, they can be expressed in matrix notation as

$$Ax = g \tag{6.11}$$

where

$$
\begin{aligned}
x' &= [x_1, ..., x_j, ..., x_{2n}] \\
&= [x_1^d, x_1^s, x_2^d, x_2^s, ..., x_n^d, x_n^s]
\end{aligned}
$$

and

$$
\begin{aligned}
a_{jj} &= F_j e_j \beta_j - \beta_j & j &= 1, 3, ..., 2n-1, \\
&= G_j e_j \delta_j - \delta_j & j &= 2, 4, ..., 2n, \\
a_{jk} &= F_j e_j \beta_k & j &= odd,\ k = odd, \\
&= F_j e_j \delta_k & j &= odd,\ k = even, \\
&= G_j e_j \beta_k & j &= even,\ k = odd, \\
&= G_j e_j \delta_k & j &= even,\ k = even, \\
g_j &= -F_j(\alpha_j - \gamma_j - (\beta_j + \delta_j)P^f) & j &= odd, \\
&= -G_j(\alpha_j - \gamma_j - (\beta_j + \delta_j)P^f) & j &= even.
\end{aligned}
$$

Equation (7.11) can be solved by matrix inversion to provide equilibrium tariffs

$$x^* = A^{-1}g \tag{6.12}$$

By varying the assumed conjectural variation (Z_{ji}), differing values of F_i and G_i, and hence different equilibrium solutions, can be obtained using the equations outlined here. These solutions will be examined in some detail.

6.1.1 The Cournot-Nash solution as a special case

To obtain a Cournot-Nash solution, the model is run with

$$Z_{ji}^{dd} = Z_{ji}^{ss} = Z_{ji}^{sd} = Z_{ji}^{ds} = 0 \quad for\ j \neq i, \tag{6.13}$$

$$Z_{ii}^{ds} = Z_{ii}^{sd} = 0, \tag{6.14}$$

$$Z_{ii}^{dd} = Z_{ii}^{ss} = 1. \tag{6.15}$$

F_i and G_i are thus

$$F_i = \beta_i / BD, \tag{6.16}$$

$$G_i = \delta_i / BD. \tag{6.17}$$

In spite of the appeal of the Cournot-Nash equilibrium, as a point from which traders would not want to move, it does not incorporate expectations of retaliation. The conjectural variations solution is more general.

6.1.2 Aggregated conjectures

Assume that each trader has an expectation as to how each rival will respond to a policy change. Thus, each of n traders has $4(n-1)$ conjectures, given prices are set differently for producers and consumers, amounting to $4n(n-1)$ individual estimates. Equation (6.37) can be used to obtain a conjectural variations solution, with equation (7.13) no longer holding.

A limitation of this approach is that expectations of interactions between rivals are not taken into account (when n exceeds 2). For example, policymakers in country 1 know how countries 2 and 3 will respond, but they assume that the resulting change in country

2's policy will not impinge on country 3. Thus, not all interactions are incorporated into the analysis. Mathematically, this is because the conjectures are partial rather than total derivatives. Total derivatives are necessary for a consistent conjectural equilibrium (in which expected responses equalled actual responses). Had such an equilibrium been found, it would provide an alternative means of finding conjectures. Total derivatives can be calculated from partial derivatives in the following fashion.

$$\frac{dx_j}{dx_i} = \Sigma_{k=1}^{n} \frac{\partial x_j}{\partial x_k} \frac{\partial x_k}{\partial x_i}. \tag{6.18}$$

For a totally interactive analysis, it is necessary to have values for all the partial derivatives (albeit that some may be zero). These conjectures may be given some arbitrary value, or they may be estimated. For example, Thursby and Jensen (1983) used arbitrary values in their two-country analysis, by assuming that the terms of trade are to be maintained. Alternatively, policy statements (threats) may provide a basis for analysis. For counterfactual simulations, a range of different assumptions could be imposed. Estimation is constrained by the need for sufficient degrees of freedom. This essentially means having $(n-1)$ years' observations for n countries.

However, for the conjectural variations model developed here, it is not necessary that each country should have conjectures about the responses of all other countries individually for the setting of optimal tariffs. As is shown by equations (7.9) and (7.10), all each country i has to estimate is F_i and G_i, (defined following equations (7.7) and ((7.8) respectively) which are the weighted sum of conjectures across all other countries. Alternatively, it is possible to deduce the implicit values of F_i and G_i from a set of observed tariffs. This approach is dependent on the strong assumption that policymakers set tariffs to maximise welfare; the estimated conjectures are those necessary to make the observed tariffs a welfare-maximising set. This is similar to the approach used in the previous chapter to estimate a weighted welfare function. The expressions for F_i and G_i are derived from the first order conditions.

$$F_i = \frac{\bar{x}_i^d \beta_i}{\alpha_i - \gamma_i - (\beta + \delta)P^f + e_i \Sigma_{j=1}^{n} (\beta_j \bar{x}_j^d + \delta_j \bar{x}_j^s)}, \tag{6.19}$$

$$G_i = \frac{\bar{x}_i^s \delta_i}{\alpha_i - \gamma_i - (\beta + \delta)P^f + e_i \Sigma_{j=1}^n (\beta_j \bar{x}_j^d + \delta_j \bar{x}_j^s)}. \tag{6.20}$$

where $\bar{x}_i$ refers to observed tariffs.

The sign of the conjectural variations estimate depends upon the relationship between actual and optimal tariffs. The aggregated conjectures are less than or greater than zero as the actual tariff is greater than or less than the optimal tariff. If actual equals optimal tariff, the conjecture is zero.

6.1.3 Conjectures and optimal tariffs

The expressions for Z_{ji} and x_i can be manipulated to provide insights into the relationship between expected retaliation and optimal tariffs. Of interest is the effect on a given tariff when tariffs change in another country, and when expectations of that response change. It is also interesting to note the impact on estimated conjectures of changes in observed tariffs. These relationships can be expressed as follows

$$\frac{\partial x_i^d}{\partial x_j^d} = \frac{-F_i e_i \beta_j}{F_i e_i \beta_i - \beta_i}, \tag{6.21}$$

$$\frac{\partial x_i^d}{\partial x_j^s} = \frac{-F_i e_i \delta_j}{F_i e_i \beta_i - \beta_i}, \tag{6.22}$$

$$\frac{\partial x_i^d}{\partial F_i} = \frac{-\beta_i(\alpha_i - \gamma_i - (\beta + \delta)P^f + e_i \Sigma_{j=1}^n (\beta_j x_j^d + \delta_j x_j^s))}{(F_i e_i \beta_i - \beta_i)^2}, \tag{6.23}$$

$$\frac{\partial F_i}{\partial \bar{x}_i^d} = \frac{\beta_i(\alpha_i - \gamma_i - (\beta_i + \delta_i)P^f + e_i(\Sigma_{j \neq i} \beta_j \bar{x}_j^d + \Sigma_{j=1}^n \delta_j \bar{x}_j^s))}{(\alpha_i - \gamma_i - (\beta + \delta)P^f + e_i \Sigma_{j=1}^n (\beta_j \bar{x}_j^d + \delta_j \bar{x}_j^s))^2}. \tag{6.24}$$

Equations (7.21) and ((7.22) show that for a given F_i an increase in tariffs in an importing country will lead to an increase in all importers' tariffs. However, an increase in an export tax (which is expressed in the negative) will result in a decrease in all importers' optimum tariffs. This confirms a result noted in the previous chapter. A trade war between importers, for example, will escalate from the initial tariff. Final tariff for each country will be greater than the optimal tariff without retaliation. A similar result holds for the export side of the market. With an export tax denoted as a negative tariff, it is apparent that with both importers and exporters involved in a trade war, the final outcome for each country will be closer to free trade than the initial no-retaliation solution.

Equation (7.23) shows that the effect of an increase in expected retaliation depends upon the direction of trade. Expected higher export taxes lead to a decrease in optimal tariffs. Likewise, expected higher import tariffs lead to a decrease in optimal taxes. The direction of movement is consistent with changes in actual taxes. An increase in tariffs in an importing country leads to a reduction in tariffs in all other importing countries. Likewise, the expectation that one country will raise tariffs leads to a fall in tariffs in the countries that hold that conjecture.

Finally, an increase in observed tariffs results in higher estimated conjectures, which are positive or negative depending once more upon the direction of trade.

Once estimated, the conjectures can be used to assess how regions or countries are likely to respond to policy changes made by their rivals. The conjectures can be varied to determine the impact of a threat or other events which change countries' beliefs about how their rivals will respond.

Having derived conjectures from an observed set of tariffs, F_i and G_i can be recalculated according to equations (7.1.2) and (7.20), and equation (7.12) can then be solved for a conjectural variations equilibrium. However, the equilibrium set of tariffs will equal the observed set. (This is one way of testing the model.) For useful analysis, it is necessary to assume constant a given set of estimated conjectures, and to change some other aspect of the model, such as the elasticities or other parameters. Here, it is assumed the United States makes an exogenous exchange rate depreciation. This can be simulated by reducing the slopes of the demand and supply functions for all countries except the United States. Let

$$\beta_i' = \beta_i \rho, \tag{6.25}$$

$$\delta_i' = \delta_i \rho, \tag{6.26}$$

where the prime denotes the demand or supply coefficient following depreciation and ρ is the new US dollar rate as a proportion of the old. With a 20 per cent depreciation $\rho = 0.8$. The impact of this is compared assuming zero and non-zero conjectural variations. An application to the world wheat trade illustrates that, by accounting for retaliation, a different and hopefully more realistic equilibrium can be attained.

6.2 Conjectural Variations in the World Wheat Market

In this section the free trade and Cournot-Nash solutions are shown. These provide a benchmark for the Cournot-Nash and conjectural variations solutions following a US dollar depreciation. The conjectures used are those estimated prior to the depreciation. The results indicate that expectations of retaliation can make a substantial difference to the trade war outcome. A summary table comparing the different solutions is presented at the end of the chapter.

6.2.1 The data

The data used here are the same as those presented in Table 5.1, with the exception that the elasticities used are long-run. To obtain long-run elasticities, the short-run values were multiplied by 4. While this is not the standard method of converting from short-run to long-run, it is consistent with the treatment of Sarris and Freebairn, who divided some of their long-run elasticities by four to convert them to short-run (p. 221). Long-run elasticities are used here because a conjectural variations solution can most sensibly be interpreted as a long-run equilibrium. The solution has an implicitly dynamic component to it, as McMillan has noted (p. 20).

In the reference period, the world price is taken to be the United States price, that is, US$158. Total trade volume is 68.2 mmt, and global welfare, with the long-run elasticities, amounts to US$58760m. Because of the linear nature of the model, the welfare levels are not very meaningful; they are included here to indicate the impact of policy changes.

6.2.2 The long-run free trade solution

The following tables show domestic consumer and producer tariffs (the difference between domestic and world prices), trade volume and welfare levels. As before, negative tariffs reflect a domestic price below the world price (export taxes or import subsidies). Negative trade volume reflects net exports, and positive values denote net imports. The model provides a disaggregation of welfare between consumers, producers and taxpayers, but this information is not shown here.

The free trade case, shown in Table 6.1, is a base equilibrium that would apply if all tariffs and taxes were removed, assuming the basic parameters remain unchanged. As well as indicating how the introduction of free trade would alter prices and trade flows, it provides a benchmark for further comparisons with tariff-ridden equilibria. The free trade solution is different from that presented in the previous chapter.

If all tariffs were removed, given the data used here, world prices would rise from the base price level of US$158/t to US$175/t. Total trade volume would be 80.8 mmt, higher than the 68.2 mmt observed in the base period. This contrasts with the short-run case, in which the free trade volume falls from its reference period level to 65.8 mmt, chiefly because the EC goes from net exports to a balanced trade (Table 5.2 and Sarris and Freebairn (1983)). With the long-run elasticities, the EC imports a substantial amount. Under free trade, welfare is improved for exporters. Most importers are worse off, although the EC is a notable winner. Global welfare with free trade is US$59787, compared with US$58680 the base period, a gain of 1.9 per cent. This is the potential benefit from complete trade liberalisation.

6.2.3 The Cournot-Nash solution

The Cournot-Nash solution is shown in Table 6.2. Countries with the greatest market power (reflecting market share and relative elasticities) impose the greatest tariff or tax. It is for this reason that taxes on the export side tend to be greater than on the import side. It is also noteworthy that producer and consumer prices are the same in each case, although there are provisions in the model for discriminating between them. This is an

Table 6.1: Tariffs, Trade and Welfare Under Free Trade.

Region	Tariff (US$/t)	Trade (mmt)	Welfare (US$m)
United States	0.00	-37.0	8588
Canada	0.00	-16.0	3309
Australia	0.00	-14.9	3132
Argentina	0.00	-5.6	2322
South Africa	0.00	-0.3	800
EC	0.00	15.1	8997
Other West Europe	0.00	4.8	2208
Japan	0.00	6.5	909
Eastern Europe	0.00	4.0	749
USSR	0.00	7.0	867
China	0.00	6.6	463
Brazil	0.00	3.8	1180
Central America & Other South America	0.00	5.8	1645
Egypt	0.00	2.4	579
Other North Africa & Middle East	0.00	12.4	12356
Other Africa	0.00	2.7	397
India	0.00	-2.8	7697
Other South Asia	0.00	-4.1	2505
South East Asia	0.00	1.2	243
East Asia	0.00	4.8	586
Rest of World	0.00	3.6	255
TOTAL		80.8	59787

Table 6.2: Cournot-Nash Tariffs, Trade and Welfare.

Region	Tariff		Trade	Welfare
	Consumer	Producer		
	(US$/t)	(US$/t)	(mmt)	(US$m)
United States	-19.71	-19.71	-30.8	8600
Canada	-8.45	-8.45	-15.4	3340
Australia	-7.85	-7.85	-14.6	3163
Argentina	-2.96	-2.96	-5.6	2334
South Africa	-0.19	-0.19	-0.4	800
EC	7.39	7.39	10.9	8953
Other West Europe	2.38	2.38	4.3	2198
Japan	3.36	3.36	6.3	895
Eastern Europe	2.06	2.06	3.9	740
USSR	3.65	3.65	6.9	852
China	3.38	3.38	6.3	448
Brazil	1.96	1.96	3.7	1171
Central America & Other South America	2.97	2.97	5.5	1633
Egypt	1.23	1.23	2.3	574
Other North Africa & Middle East	6.34	6.34	11.5	12327
Other Africa	1.40	1.40	2.7	391
India	-1.76	-1.76	-2.9	7703
Other South Asia	-2.31	-2.31	-4.1	2514
South East Asia	0.62	0.62	1.2	240
East Asia	2.46	2.46	4.7	575
Rest of World	1.86	1.86	3.5	247
TOTAL			73.8	59701

intuitively appealing result, reflecting equal welfare weights on consumers, producers and taxpayers. Unequal weights result in differential prices. With the imposition of tariffs, the world price rises to US$178, marginally above the free trade level of US$175. Trade volume and global welfare are below the free trade level. However, due to their market power, exporters have increased their welfare, albeit marginally; importers have had theirs decreased, in spite of the optimum tariffs they have imposed. These results confirm those obtained from the one-price model.

Table 6.3: Cournot-Nash Equilibrium Following Depreciation.

Region	Tariff		Trade	Welfare
	Consumer	Producer		
	(US$/t)	(US$/t)	(mmt)	(US$/t)
United States	-31.65	-31.65	-39.6	10115
Canada	-9.72	-9.72	-14.8	4053
Australia	-9.18	-9.18	-14.4	3839
Argentina	-3.39	-3.39	-5.3	2874
South Africa	-0.20	-0.20	-0.3	998
EC	10.54	10.54	13.2	11307
Other West Europe	3.23	3.23	4.9	2785
Japan	4.12	4.12	6.5	1169
Eastern Europe	2.50	2.50	4.0	956
USSR	4.47	4.47	7.1	1119
China	4.22	4.22	6.6	612
Brazil	2.45	2.45	3.9	1494
Central America & Other South America	3.76	3.76	5.9	2086
Egypt	1.65	1.65	2.6	737
Other North Africa & Middle East	7.98	7.98	12.1	15506
Other Africa	1.76	1.76	2.8	510
India	-1.09	-1.09	-1.5	9610
Other South Asia	-2.21	-2.21	-3.3	3112
South East Asia	0.76	0.76	1.2	310
East Asia	3.02	3.02	4.8	756
Rest of World	2.33	2.33	3.7	337
TOTAL			79.2	74285

6.2.4 A 20 Per Cent USA Depreciation

The Cournot-Nash solution following a 20 per cent depreciation of the US dollar is shown in Table 6.3. Compared with the previous Cournot-Nash solution, world price has risen from US$178 to US$214, and global welfare has increased by 24 per cent in US dollar terms. As expected, optimum taxes, trade flow and welfare for the United States and all importers have risen. American producers and taxpayers have benefitted at the expense of consumers. Competing exporters suffer reduced trade volume, but all groups have benefitted, in US dollar terms, from higher world and domestic prices.

6.2.5 The conjectural variations trade war solution

The conjectural variation estimates are shown in Table 6.4 along with the post-depreciation conjectural variations solution. The conjectural variation estimates are prior to depreciation. $F_i - \frac{\beta_i}{BD}$ refers to changes in response to consumer prices. $G_i - \frac{\delta_i}{BD}$ refers similarly to producer prices. The estimates are not percentage changes; they are based on a unit change in x_i. They show the weighted change in rivals' tariffs in response to a unit change in each country's tariff consistent with welfare maximisation. In other words, for the observed tariffs to be optimal, each country must have the conjectures indicated.

In general, the estimates indicate that only a small change in expectations of retaliation is necessary to significantly alter the optimum tariff. In countries with observed tariffs of zero, such as the United States in this period, the conjectures are negative, indicating that a zero tariff policy is consistent only with the expectation that the weighted sum of other traders' tariffs would fall. This would result in a decline in world and United States export prices.

Table 6.4 can be compared with Table 6.3 to assess the impact of conjectural variations on prices, trade flow and welfare. Assuming countries hold the same expectations of retaliation after depreciation as before, the resulting tariffs and trade flows are as shown in Table 6.4. Countries, such as the United States, which preferred zero tariffs have maintained that level. In general, where observed tariffs and taxes were non-zero, they have risen in US dollar terms. However, world price at US$178 is below the revised Cournot-Nash level of US$214. Global welfare at US$72661m is down 2.2 per cent on the Cournot-Nash equivalent. These results illustrate that non-zero conjectures can significantly influence perceived optimum price levels.

Australia's influence as a small exporter is minimal in a noncooperative environment. Suppose Australia had observed consumer and producer tariffs at the Cournot-Nash level of -US$7.85. How would this affect the post-depreciation conjectural variations solution? Australia's estimated conjectures and optimum tariff would, of course, be zero. Trade volume would fall to 12.9 mmt, but welfare would rise to US$3340m. Other exporters would benefit through increased trade flow. Trade flow from the US would increase to 38.8 mmt. On the importing side, conjectures, tariffs and trade would increase but welfare

Table 6.4: Conjectural Variations Equilibrium Following Depreciation

Region	$F_i - \frac{\beta_i}{BD}$	$G_i - \frac{\delta_i}{BD}$	Tariff Consumer (US$/t)	Tariff Producer (US$/t)	Trade (mmt)	Welfare (US$m)
United States	-0.053	-0.168	0.00	0.00	-38.0	8696
Canada	-0.006	-0.042	0.00	0.00	-12.8	3546
Australia	-0.012	-0.022	20.08	0.00	-13.4	3336
Argentina	0.047	0.205	-38.56	-38.56	-3.2	2676
South Africa	-0.228	-0.003	7.39	0.00	-0.1	991
EC	0.338	0.663	102.22	102.22	-6.6	10314
Other West Europe	0.340	0.586	97.53	97.53	0.2	2638
Japan	0.149	0.020	55.66	775.24	6.0	1330
Eastern Europe	-0.005	0.000	0.00	0.00	4.3	1106
USSR	-0.014	0.000	0.00	0.00	8.0	1392
China	-0.023	0.000	0.00	0.00	8.1	880
Brazil	-0.050	0.087	-11.03	73.05	4.5	1634
Central America & Other South America	0.051	0.017	16.80	16.80	6.8	2324
Egypt	-0.478	-0.092	-58.00	-58.00	6.2	793
Other North Africa & Middle East	0.209	0.050	58.49	58.49	10.9	15879
Other Africa	0.099	0.013	23.60	23.60	3.0	619
India	-0.089	-0.042	0.00	0.00	5.8	9683
Other South Asia	2.078	0.827	14.71	14.71	-1.1	3046
South East Asia	-0.025	-0.002	-10.49	-10.49	1.4	355
East Asia	-0.010	0.000	0.00	0.00	5.4	940
Rest of World	-0.013	0.000	0.00	0.00	4.5	485
TOTAL					75.2	72661

would fall. For example, the EC's conjectures would rise from .338 and .663 (see Table 6.3) to .340 and .667, and its tariffs would rise by US$0.04. Trade flow would rise to 6.7 mmt, but welfare would fall to US$10300m.

6.3 A Review

The impact of expectations of retaliation on a trade war outcome has been examined. This is a refinement of the Cournot-Nash equilibrium, in which traders are assumed to expect

Table 6.5: Comparative Solutions

Solution	Price (US$/t)	Trade (mmt)	Welfare (US$m)
Base Period	158	68.2	58680
Free Trade	175	80.8	59787
Cournot-Nash	178	73.8	59701
CN (Post-Dep)	214	79.2	74285
Conjectural Variations (Post-Dep)	178	75.2	72661

their rivals not to retaliate. The effect of an increase in expected retaliation depends upon the direction of trade. Optimal tariffs decrease if exporters are expected to raise their taxes in response. Similarly, optimal export taxes decrease if importers are expected to raise tariffs. However, optimal export taxes will rise if rival exporters are expected to raise taxes in retaliation. A similar positive relationship holds for importers. Thus, the overall effect of a threat to raise taxes is, a priori, indeterminate, as importers and exporters respond in ways which have opposite effects on the direction of movement of the world price.

In the empirical analysis, conjectures were estimated by aggregating for each country the response of all $n - 1$ countries. A trade war equilibrium following an exogenous exchange rate shock was calculated using these conjectures. A summary of the results of this chapter is presented in Table 6.5. Trade, world price and global welfare were found to be substantially affected by the expectations of retaliation.

Chapter 7

Dynamic Trade Games

7.1 Introduction

The analysis of retaliation in Chapters 5 and 6 is limited by the static nature of the supply response and the retaliatory response. Producers are limited by various adjustment costs and information gathering costs, in addition to the time that elapses between the planning of production and delivery or sale of the product. Farmers' expectations of future prices may also reflect realised prices for a number of years in the past, suggesting the need for some form of distributed lag model. Likewise, policymakers may be constrained in their decision making by a variety of institutional impediments, and the need to consult with a range of interest groups, which may transverse national boundaries. Some of these effects can be captured in static models by the use of long-run elasticities, but nothing is revealed about the path to equilibrium, nor can much be said about the speed of adjustment. Dynamic models allow for intertemporal combinations of behaviour which can never be captured in a static model. The use of wheat export subsidies may be seen as an example of such behaviour. More distant returns can be discounted, with later returns traded off against those obtained early in the time horizon.

The objective in this chapter [1] is to present a dynamic framework for analysing strategic behaviour in international trade. Specifically, might policies which are sub-optimal in a short-run context, such as export subsidies, be optimal in the long run? The impact of changes in discount rates and the time horizon on policy is assessed. The effects on optimal policy of differing speeds of adjustment on the supply side are ascertained. The impact of a supply side shock is used to determine whether tariffs, when set at their optimal levels, have a stabilising or destabilising effect on world prices. Finally, the effect on a trade war of weighted welfare functions is determined.

In the next section a Cournot-Nash noncooperative dynamic difference game is formulated under differing supply price expectation assumptions. The first lag structure is the cobweb model, in which the suppliers' expected price is equivalent to the price in the previous period. The extrapolative (or regressive) expectations model is based on a two-period lag, in which the influence of each period depends upon the value of an adjustment coefficient. Once the supply and demand functions are specified, a set of tariffs or taxes which maximises a welfare function over the specified time horizon is found. Analysis is conducted with a discrete-time model, in which tariffs are set at the beginning of each period. As wheat is an annual crop, the most suitable time period is one year. The analysis can accommodate different welfare weights for consumers, producers and taxpayers.

Once the basic model has been specified, a free trade solution, assuming zero tariffs, is calculated to provide a benchmark for later comparisons. Next, an optimal control procedure is used to find the welfare maximising set of tariffs over the time horizon. These tariffs are found for each country. An iterative procedure is used to find a set of tariffs for each country with other countries' responses taken into account. By this means a dynamic Cournot-Nash equilibrium is found. Welfare, trade and price effects are analysed under differing assumptions regarding supply lags, time horizon and discount rates.

As with the static models, the analysis is applied to the wheat market, using data, in the first instance, for the base period 1978-79 to 1979-80. Short-run elasticities are used, as these are consistent with the annual time period of the model. Unless otherwise specified, the assumptions relevant to the static version of the model also hold for the dynamic version.

[1] Some of the material in this chapter appeared in Vanzetti and Kennedy (1988d) and Vanzetti (1988).

7.2 A Dynamic Linear Trade Model

Once demand and supply equations and equilibrium conditions are specified, a welfare function is derived for each trader. This can be expressed in terms of linear and quadratic multiples of a state vector[2] of endogenous variables (prices and tariffs). The dynamic difference equations (or state equations) describe the evolution of the state vector over time. An optimal set of controls (tariffs) can be obtained by differentiation of the welfare function. The controls can be solved by backward induction using Riccati equations, or simultaneously for all time periods[3]. Once the single country optimal control solution is obtained, a Cournot-Nash dynamic game solution is found by iteration. The model will now be described in detail.

Consider an homogeneous product traded between n countries with linear demand and supply curves

$$D_{it} = \alpha_i - \beta_i(P_t + x_{it}), \tag{7.1}$$

$$S_{it} = \gamma_i + \delta_i(P_t^e + x_{it-1}), \tag{7.2}$$

where D_{it} and S_{it} denote quantities demanded and supplied in country i in period t; P_t and P_t^e denote the current world price and the price producers expect to receive in period t; x_{it}, the tariff, is the difference between the domestic and world prices; and α_i, β_i, γ_i and δ_i refer to the usual intercept and slope parameters, which are all non-negative and assumed constant across all time periods.

Let

$$P_t^e = P_{t-1} + \epsilon_i(P_{t-1} - P_{t-2}) \tag{7.3}$$

where ϵ_i is the coefficient of adjustment, which indicates the weights attached by producers to previous prices in forming their expectations of the current period's price. The parameter would normally be expected to be between -1 and 0, implying a positive supply response to a price increase. This specification of P^e implies a cobweb model if ϵ_i

[2]In this case, the (augmented) state vector also contains controls, as these appear in the welfare function. It shall nonetheless be referred to as a 'state vector', because control variables can be redefined as state variables simply by increasing the dimension of the state vector.

[3]The simultaneous method is described in Appendix G.

is zero, and hence suppliers respond to price lagged one period only, and an extrapolative (or regressive) expectations model if ϵ_i is nonzero. Any finite number of lags can be modelled, although the complexity increases rapidly with the lag length. Note that equations (8.2) and (8.3) imply that producers react to their own country's tariffs with a one-period lag, but their expectation of world prices is a function of prices in the previous two periods. This would be the case if producers know their own country's trade policies prior to cropping, but did not know other countries' policies. (With known demand and supply parameters, other countries' tariffs provide the only uncertainty for the domestic producer.) Producers are assumed to lack the information available to policymakers, and so base their price expectations on previous prices, rather than on forward-looking expectations[4]. This eliminates a game between policymakers and private agents (producers). By contrast, policymakers have better information and are able to act as rational optimisers. For this reason, policymakers consider actual producer surplus, rather than the expected surplus on which producers make their decisions.

Assuming no change in stocks, and therefore market clearance

$$\Sigma_{i=1}^{n}(D_{it} - S_{it}) = 0. \tag{7.4}$$

The market clearing free trade price is

$$P_t^f = H + f(1 + \epsilon_i)P_{t-1} - f\epsilon_i P_{t-2} \tag{7.5}$$

where

$$f = \frac{-\Sigma_{i=1}^{n}\delta_i}{\Sigma_{i=1}^{n}\beta_i}, \tag{7.6}$$

$$H = \Sigma_{i=1}^{n}(\alpha_i - \gamma_i)/\Sigma_{i=1}^{n}\beta_i. \tag{7.7}$$

With tariffs, the market clearing world price becomes

$$P_t = H + f(1 + \epsilon_i)P_{t-1} - f\epsilon_i P_{t-2} - \frac{\Sigma_{i=1}^{n}(\beta_i x_{it} + \delta_i x_{it-1})}{\Sigma_{i=1}^{n}\beta_i}. \tag{7.8}$$

[4] The rational expectations model has no role in a deterministic model such as this. The price lag is the only link between time periods. With rational expectations and no disturbance term, the link between periods is removed.

Once the world price equation is specified, the welfare function can be described. Weights can be attached to the surplus going to consumers, producers and taxpayers. With linear schedules, the total welfare function to be maximised for country i over the time horizon T is

$$W_i = \Sigma_{t=1}^{T}\psi^t(w_{ci}CS_{it} + w_{pi}PS_{it} + w_{gi}TR_{it}) \tag{7.9}$$

with

$$\begin{aligned} CS_{it} &= \frac{D_{it}^2}{2\beta_{it}}, & (7.10)\\ PS_{it} &= \frac{S_{it}^2 - \gamma_{it}^2}{2\delta_{it}} + S_{it}(P_t + x_{it} - P_t^e - x_{it-1}), & (7.11)\\ TR_{it} &= (D_{it} - S_{it})x_{it}. & (7.12)\end{aligned}$$

CS_{it}, PS_{it} and TR_{it} refer to consumer surplus, producer surplus and tariff revenue respectively, and ψ is an appropriate real discount factor. As noted, the surplus measured by PS_{it} is actual, rather than expected, surplus. Producers expect to receive price P_t^e, but actually receive P_t. D_{it} and S_{it} now depend on x_{jt} and x_{jt-1} for all j.

For any given period t, welfare for country i can be represented as

$$\begin{aligned} W_{it} = {} & w_{ci}(\frac{\alpha_i^2}{2\beta_i} - \alpha_i P_t - \alpha_i x_{it} + \frac{\beta_i}{2}P_t^2 + \beta_i P_t x_{it} + \frac{\beta_i}{2}x_{it}^2) \\ & + w_{gi}(\alpha_i x_{it} - \beta_i P_t x_{it} - \beta_i x_{it}^2 - \gamma_i x_{it} - \delta_i\epsilon_i x_{it}P_{t-1} \\ & + \delta_i\epsilon_i x_{it}P_{t-2} - \delta_i x_{it}x_{it-1} - \delta_i x_{it}P_{t-1}) \\ & + w_{pi}(\frac{\gamma_i^2}{2\delta_i} + \gamma_i P_t + \gamma_i x_{it} + \delta_i\epsilon_i P_t P_{t-1} - \delta_i\epsilon_i P_t P_{t-2} + \delta_i P_t x_{it-1} \\ & + \delta_i P_t P_{t-1} - \frac{\delta_i}{2}\epsilon_i^2 P_{t-1}^2 + \delta_i\epsilon_i^2 P_{t-1}P_{t-2} - \frac{\delta_i}{2}\epsilon_i^2 P_{t-2}^2 \\ & + \delta_i\epsilon_i x_{it}P_{t-1} - \delta_i\epsilon_i x_{it}P_{t-2} - \delta_i\epsilon_i x_{it-1}P_{t-1} + \delta_i\epsilon_i x_{it-1}P_{t-2} \\ & - \delta_i\epsilon_i P_{t-1}^2 + \delta_i\epsilon_i P_{t-1}P_{t-2} + \delta_i x_{it}x_{it-1} + \delta_i x_{it}P_{t-1} - \frac{\delta_i}{2}x_{it-1}^2 \\ & - \delta_i x_{it-1}P_{t-1} - \frac{\delta_i}{2}P_{t-1}^2) \end{aligned} \tag{7.13}$$

This can more conveniently be expressed in matrix form as

$$W_{it} = r'_{it}y_{it} + \frac{1}{2}y'_{it}K_{it}y_{it} \tag{7.14}$$

where r_i is an n vector of linear coefficients, y_i is an n vector of state variables, and K_i an

nxn matrix of quadratic coefficients, where n equals five, in this case. (The off-diagonal terms in K_i are of course the coefficients of the multiplicative terms in the welfare function, and K_i is symmetric.)

Explicitly,

$$r_i' = [-w_{ci}\alpha_i + w_{pi}\gamma_i, (w_{gi} - w_{ci})\alpha_i + (w_{pi} - w_{gi})\gamma_i, 0, 0, 0], \tag{7.15}$$

$$y_{it}' = [P_t, x_{it}, P_{t-1}, x_{it-1}, P_{t-2}], \tag{7.16}$$

and

$$K_i = \begin{bmatrix} w_{ci}\beta_i & (w_{ci} - w_{gi})\beta_i & w_{pi}\delta_i(1 + \epsilon_i) & w_{pi}\delta_i & -w_{pi}\delta_i\epsilon_i \\ (w_{ci} - w_{gi})\beta_i & (w_{ci} - 2w_{gi})\beta_i & (w_{pi} - w_{gi})\delta_i(1 + \epsilon_i) & (w_{pi} - w_{gi})\delta_i & (w_{gi} - w_{pi})\delta_i\epsilon_i \\ w_{pi}\delta_i(1 + \epsilon_i) & (w_{pi} - w_{gi})\delta_i(1 + \epsilon_i) & -w_{pi}\delta_i(1 + \epsilon_i + \epsilon_i^2) & -w_{pi}\delta_i(1 + \epsilon_i) & w_{pi}\delta_i(\epsilon_i + \epsilon_i^2) \\ w_{pi}\delta_i & (w_{pi} - w_{gi})\delta_i & -w_{pi}\delta_i(1 + \epsilon_i) & -w_{pi}\delta_i & w_{pi}\delta_i\epsilon_i \\ -w_{pi}\delta_i\epsilon_i & (w_{gi} - w_{pi})\delta_i\epsilon_i & w_{pi}\delta_i(\epsilon_i + \epsilon_i^2) & w_{pi}\delta_i\epsilon_i & -w_{pi}\delta_i\epsilon_i \end{bmatrix}_{(5x5)} \tag{7.17}$$

The K_i matrix simplifies considerably if either all the weights are unity, or if ϵ_i equals zero, or both. This is shown in Appendix H.

The evolution of the state equation is given by

$$y_{it} = A_i y_{it-1} + b_i x_{it} + c_i \tag{7.18}$$

where A_i, b_i and c_i are a constant (for each country) nxn matrix and n vectors respectively, and the control x is a scalar. The A_i, b_i, and c_i matrices are shown in more detail.

$$A_i = \begin{bmatrix} f(1+\epsilon_i) & \frac{\delta_i}{\Sigma\beta_i} & -f\epsilon_i & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{bmatrix}_{(5x5)} \tag{7.19}$$

$$b_i' = [\frac{-\beta_i}{\Sigma\beta_i}, 1, 0, 0, 0] \tag{7.20}$$

$$c_i' = [H - \frac{\Sigma_{j\neq i}(\beta_j x_{jt} + \delta_j x_{jt-1})}{\Sigma\beta_i}, 0, 0, 0, 0] \tag{7.21}$$

Thus far we have an expression for welfare for any given period. To generalise over all T periods, it is necessary to find a set of feedback equations expressing a rule for x_t as a function of y_{t-1}. A variety of methods of doing this exist. The procedure used in this chapter involves backward induction to find a set of difference equations in r_i and K_i. These are known as Riccati equations, and utilise the 'Principle of Optimality' by which once the optimal policy has been found (in terms of y_{t-1}), it is not changed by earlier policies[5].

Consider the optimisation problem for each country (dropping the i subscript) for the

[5]A useful illustration of the Principle of Optimality is a simple shortest route transport problem. Consider travelling between two cities. From a given point on the route the shortest path to the destination will be the same no matter how one arrived at that given point. Once known, that part of the route need not be planned again. The Principle of Optimality is the basis of dynamic programming.

final period T.

$$V_T\{y_{T-1}\} = \underset{\{x_T\}}{Max}\, \psi(r_T' y_T + \frac{1}{2} y_T' K_T y_T) \quad (7.22)$$

$$s.t. \;\; y_T = A y_{T-1} + b x_T + c \quad (7.23)$$

where $V_t\{y_{t-1}\}$ is the present value obtained from following the optimal sequence of tariffs from period t to period T. Equation (8.23) can be substituted into (8.22) to obtain

$$\begin{aligned} W_T = {} & \psi(r_T' A y_{T-1} + r_T' b x_T + r_T' c + \frac{1}{2}[y_{T-1}' A' K_T A y_{T-1} + y_{T-1}' A' K_T b x_T \\ & + y_{T-1}' A' K_T c + x_T' b' K_T A y_{T-1} + x_T' b' K_T b x_T + x_T' b' K_T c + c' K_T A y_{T-1} \\ & + c' K_T b x_T + c' K_T c]) \end{aligned} \quad (7.24)$$

The first order conditions are obtained by differentiating the objective function with respect to the control vector. The partial derivatives are then equated to zero, for an interior solution, and solved for the optimal tariff

$$\frac{\partial W_T}{\partial x_T} = \psi(r_T' b + A' K_T b y_{T-1} + b' K_T b x_T + b' K_T c) = 0 \quad (7.25)$$

This gives

$$x_T^* = G_T y_{T-1} + g_T \quad (7.26)$$

where

$$G_T = -\psi(b' K_T b)^{-1} b' K_T A, \quad (7.27)$$

and

$$g_T = -\psi(b' K_T b)^{-1} b'(K_T c + r). \quad (7.28)$$

Equation (8.26) is the feedback equation, expressing x_t as a function of the previous period's state vector. Given y_{T-1},

$$V_T\{y_{T-1}\} = \psi(r_T' y_T^* + \frac{1}{2} y_T'^* K_T y_T^*) \quad (7.29)$$

where

$$y_T^* = A y_{T-1} + b x_T^* + c. \quad (7.30)$$

Hence, equation (8.26) holds regardless of earlier values of x. Thus, having found x_T to maximise W_T, it is necessary only to find x_{T-1} to maximise

$$V_{T-1}\{y_{T-2}\} = \underset{\{x_{T-1}\}}{Max}\,[\psi(r'_{T-1}y_{T-1} + \frac{1}{2}y'_{T-1}K_{T-1}y_{T-1}) + \psi^2 V_T\{y_{T-1}\}]. \quad (7.31)$$

To express this in terms of y_{T-1} and x_{T-1}, y_T must be removed by substituting equation (8.30) into (8.29). Collection of terms yields

$$\begin{aligned} = \; & \underset{\{x_{T-1}\}}{Max}\; \psi[\frac{1}{2}y'_{T-1}\Phi y_{T-1} + \frac{1}{2}x'_{T-1}\Theta x_{T-1} \\ & + y'_{T-1}\Psi x_{T-1} + \phi y_{T-1} + \theta'_{T-1}x_{T-1} + \eta,] \end{aligned} \quad (7.32)$$

where

$$\begin{aligned} \Phi &= \psi A'K_T A + K_{T-1}, \\ \Theta &= \psi b'K_T b, \\ \Psi &= \psi A'K_T b, \\ \phi &= \psi A'(K_T c + r_T) + r_{T-1}, \\ \theta &= \psi b'(K_T c + r_T), \\ \eta &= \psi(c'K_T c + r'_T c). \end{aligned} \quad (7.33)$$

To find the optimum, this equation is differentiated with respect to x_{T-1}, and set to zero for a maximum. Setting the right hand side of equation (8.32) equal to zero yields

$$x^*_{T-1} = -(\Theta'_{T-1})^{-1}\Psi_{T-1}y_{T-1} - (\Theta'_{T-1})^{-1}\theta_{T-1} \quad (7.34)$$

As before, the feedback equation can be substituted into the welfare equation to give

$$V_{T-1}\{y_{T-2}\} = r'_{T-1}y'^*_{T-1} + \frac{1}{2}y'^*_{T-1}K_{T-1}y^*_{T-1} + \psi V_T\{y^*_{T-1}\} \quad (7.35)$$

where

$$K_{T-1} = \Phi_{T-1} + G'_{T-1}\Theta_{T-1}G_{T-1} + 2\Psi_{T-1}G_{T-1} \quad (7.36)$$

$$r_{T-1} = (\Psi_{T-1} + G'_{T-1}\Theta'_{T-1})g_{T-1} + G'_{T-1}\theta_{T-1} + \eta_{T-1}. \quad (7.37)$$

The equations are general for all periods and are the Riccati equations. They can also be expressed as

$$K_{t-1} = A'K_tA + U_{t-1} - [A'K_tb][b'K_tb]^{-1}[b'K_tA] \quad (7.38)$$

$$r_{t-1} = -[A'K_tb][b'K_tb]^{-1}b'[K_tc + r_t] + A'[K_tc + r_t] + u_{t-1} \quad (7.39)$$

by substituting for $\Phi, \Theta, \Psi, \phi, \theta$ and η. U and u are the initial quadratic and linear coefficients for the particular period. The Riccati equations essentially update these coefficients. As the equations are backward recursive, it is necessary to solve for period $T-1$ first (given the terminal conditions K_T and r_T), then $T-2$ and so forth. Once all the Riccati equations are found, the feedback rule and the systems equation are used to find the solution[6].

The foregoing is an description of the single controller problem, in which only one objective function is maximised. The solution to the single controller problem provides an optimal set of tariffs if rival countries do not respond. However, if rivals do respond, and a trade war occurs, it is necessary to take this into account. The game solution used here is Cournot-Nash.

The dynamic Cournot-Nash equilibrium is obtained by an iterative procedure. First, the optimal set of tariff over the specified time horizon is found for country 1, assuming all other countries have zero tariffs. Next, country 2's optimal tariffs are found taking into account country 1's tariffs. These are included in the first element in the c vector. This is shown in equation (8.21). Tariffs are successively found for all countries with tariffs determined earlier taken into account. The procedure is continued until convergence is obtained. Convergence is hastened by updating the tariffs at each individual country's solution, rather than at the completion of each iteration. Such an iteration is carried out in the next section[7].

[6] A derivation of a similar although more complex problem to that presented here can be found in Kendrick (1981). Kendrick's model contains a lag between the control and the state vectors. This makes no difference to the analysis in deterministic models. He also has multiplicative terms in his objective function (p. 13).

[7] When applied to a twenty one region model, convergence occurs in about 10 iterations, and takes about 20 seconds of cpu time on a Vax 8800. The single controller problem takes less the one second. At convergence, the USA first period tariff differs by less than one per cent from its previous value.

7.3 The World Wheat Market with Lagged Supply Response

Although the model presented in this chapter is quite abstract, it can be used to show the impact of trade policies over time, and to demonstrate the importance of assumptions regarding supply response, time horizons, discount rates and the policymakers' preference function. These factors affect the way the model responds to an exogenous shock, such as an exchange rate change or a drought-induced supply shift. First, for comparative purposes, optimal tariffs without retaliation are presented. The effect of different lags, discount rates and time horizons on these tariffs is shown. Next, the impact of these factors on the Cournot-Nash trade war solution is examined.

7.3.1 The data

The data used in Chapter 5 are used here. They are presented in Table 6.1. The elasticities are short-run, befitting a dynamic model with an annual periodicity. In the reference period, the world price is taken to be the United States price, that is, US$158. Total trade volume is 68.2 mmt. Because of the linear nature of the model, and the short-run nature of the elasticities, welfare levels are overestimated; they are included here to indicate the impact of policy changes.

7.3.2 Stability

Before examining the dynamic solution, a mention of the stability properties of the model is timely. In a simple cobweb model, with no tariffs, successive values of the price are determined by the relative slopes of the supply and demand curves. Convergence occurs if the slope of the supply curve is less than the slope of the demand curve, that is, $\delta_i < \beta_i$. The greater the difference in slopes, the faster the convergence. If the slopes are the same, price oscillations of constant amplitude occur. In an extrapolative model, such as the one proposed in this chapter, the lag in response dampens the oscillations, and convergence is achieved more quickly. The stability condition is $(\delta_i + \epsilon_i) < \beta_i$. Recall that

ϵ is negative. The analysis is more complicated when tariffs are involved. Stability and speed of convergence can be ascertained by examining the eigenvalues of the A_i matrix. The A matrix expresses the relationship between successive state vectors. The whole A matrix, rather than just the a_{11} element, must be examined. With a one period lag, the eigenvalues of the A matrix must be less than one, in absolute value, for convergence to occur. If some values are greater than one, the eigenvectors reveal the nature of the final equilibrium. With a two-period lag the A_i matrix is modified as follows

$$A_i^* = \begin{bmatrix} A_i & b_i \\ I & 0 \end{bmatrix}_{(10x10)}$$

where I is an identity matrix, and A and b are as previously denoted. Zeros make up the remainder of the square matrix. Each eigenvalue is a complex number which has a real and imaginary component. Eigenvalues with absolute value of less than one are consistent with convergence. As an example, with $\epsilon = -0.3$, the first, ninth and tenth (of ten) eigenvalues for the USA are (-.72, 0.00), (.0008, -.63) and (.0008, .63). The remainder are zero. These numbers, being considerably less than one, indicate that convergence occurs within a few periods. The eigenvalues for all countries are less than one.

7.3.3 Optimal tariffs without retaliation

For comparative purposes, a reminder of the static results is useful. In the static case, reported in Chapter 5, world prices would rise from the base price level of US$158/t to US$175/t if all tariffs were removed. Total trade volume would be 65.8 mmt, lower than the 68.2 mmt observed in the base period, chiefly because the EC ceases to be an exporter. Under free trade, the welfare of exporters is increased. Most importers are worse off, although the EC is a notable winner. The optimal export tax for the USA is $70. This is shown in Table 5.4.

To assess the dynamics in the model, it is instructive to examine tariffs and world prices for one country when no retaliation occurs. Because of its dominance in the world wheat trade, export taxes for the USA are presented here. Assume that the USA sets its optimal export tax, and that retaliation does not occur. All other regions maintain a free trade policy.

Alternative lag structures

Ideally, empirical estimates of the lag coefficient would be obtained for each country. No attempt has been made to do this, due to the difficulties in obtaining or making empirical estimates. Instead, a reasonable coefficient is imposed, and is assumed to be the same for all countries, and for all time periods. It could, of course, be varied. Some sensitivity analysis is undertaken to gauge the reasonableness of the coefficient value.

Taxes and prices are shown for three lag structures, with ϵ set at 0, -0.3 and -0.6. An ϵ of -0.3 indicates that producers put a weight of 0.7 on the one-period lagged price and 0.3 on the price lagged two periods. A coefficient of zero corresponds to the cobweb model, whereas -0.6 indicates the producers put more weight on prices two periods past than the more recent past. Neither of these are intuitively appealing, and they can be seen as extreme values. The discount rate is zero, and the model is run over 20 years. Period 0 shows the initial free trade situation.

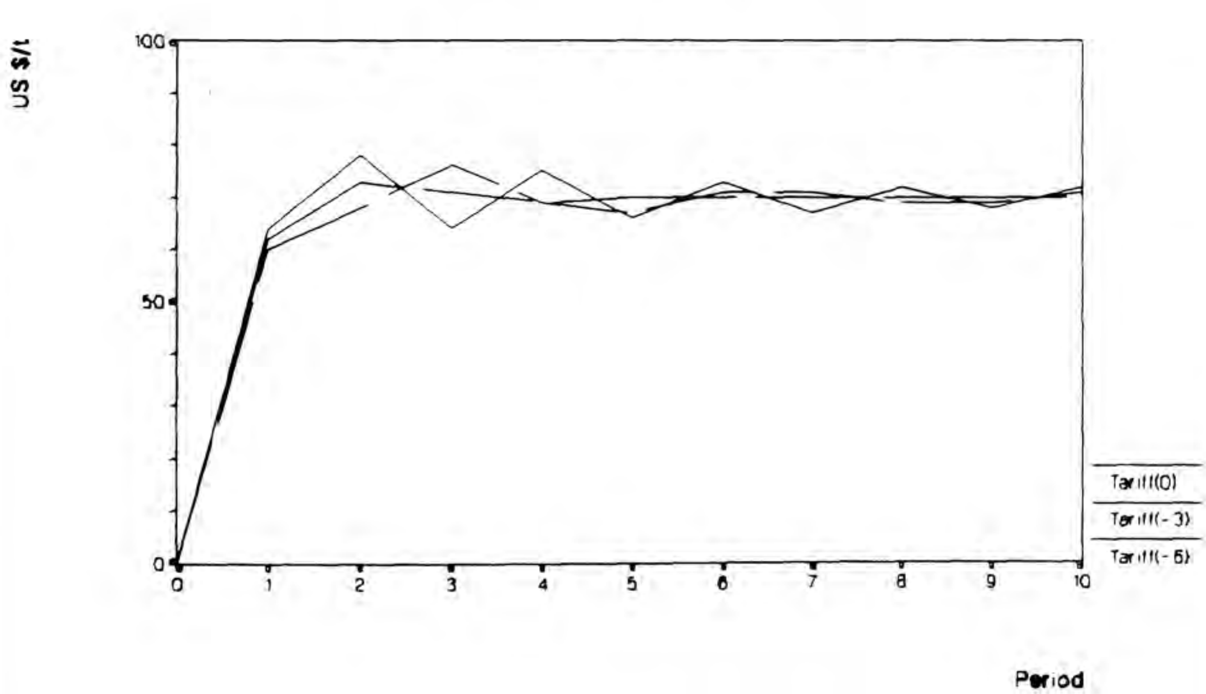
In Table 8.3.3, domestic taxes (the difference between domestic and world prices) and trade volume are shown. The results can be seen more readily in Figure 7.1.

In all three cases, taxes oscillate somewhat, but dampen quite quickly for the central value of ϵ, and complete convergence is achieved after about five periods. The model converges to the same value as in the static model, as is to be expected. The cobweb model does not reach convergence within twenty periods. The reason for this can be ascertained by examining the eigenvalues. The first is -1.15, implying that the cobweb model will not converge. The final model has all eigenvalues below unity, in absolute terms, yet it does not converge within ten periods. There appears to be little difference in stability and speed of convergence in tariffs for coefficient values between -0.2 and -0.4. However, values as extreme as -0.1 and -0.5 induce instability and the absence of complete convergence. An ϵ of -0.3 will be used in all further analysis, as it is intuitively more satisfying than the two extremes, and provides the most rapid convergence.

Table 7.1: USA Export Taxes and World Prices Without Retaliation: Alternative Lag Structures (US$/t)

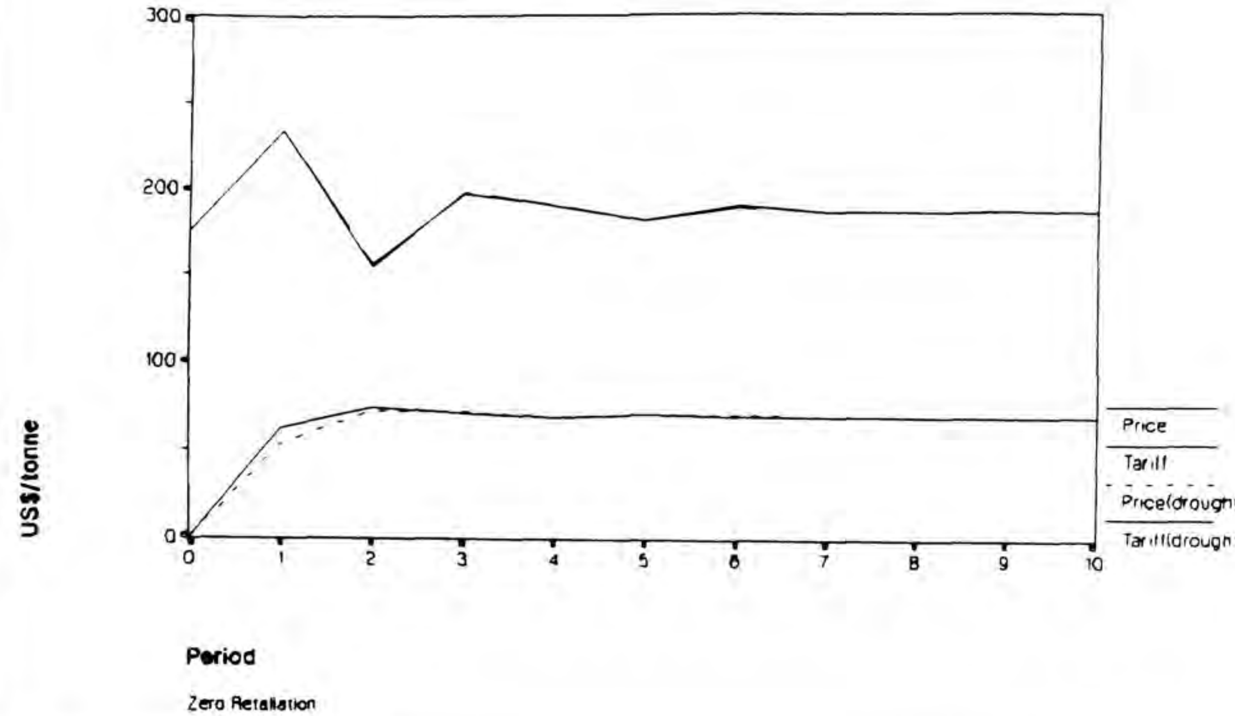
Period	$\epsilon = 0$		$\epsilon = -0.3$		$\epsilon = -0.6$	
	x	P	x	P	x	P
0	0	175	0	175	0	175
1	-64	181	-62	235	-60	288
2	-78	195	-73	157	-68	153
3	-64	184	-71	197	-76	142
4	-75	192	-69	192	-69	231
5	-66	186	-70	183	-67	199
6	-73	190	-70	191	-71	157
7	-67	187	-70	188	-71	195
8	-72	189	-70	188	-69	205
9	-68	188	-70	189	-69	177
10	-72	188	-70	188	-71	182

Figure 7.1: Alternative Lag Structures



Source Table 7.1

Figure 7.2: Four and Ten Year Time Horizons

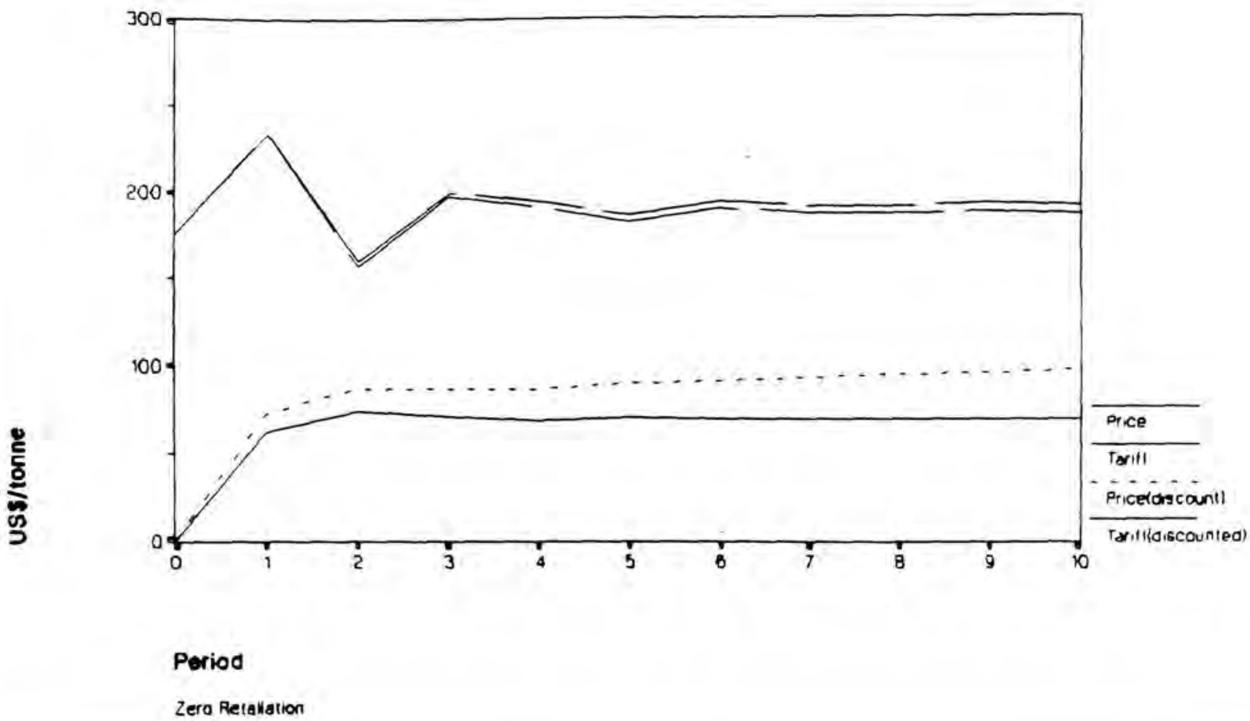


Alternative time horizons

In Table 7.1, the time horizon for all policymakers is 20 years. However, in some circumstances a shorter horizon may be more realistic, especially if elections are considered to have a significant impact on the policy making process, and given the influence of the rural lobby in many developed countries. To assess the impact of a shorter time horizon, optimal taxes were calculated for the USA assuming a ten year and a four year horizon. Results can be seen in Figure 7.2. The adjustment coefficient has been held at -0.3, and there is no discounting. Taxes for the four periods are similar to the final four periods in the ten year scenario. However, the first period is significantly higher, reflecting the free trade starting position. Results are dominated by the situation at the end of the period, the terminal conditions, rather than the initial conditions. In spite of this, world price is heavily influenced by the initial conditions, due to the lags involved. The final period's price has risen due to the tariff increase in the last period. Average world price, trade flow and global welfare have risen. Clearly, the time horizon is an important factor, even without retaliation.

However, one problem with the short time horizons is the influence of the terminal conditions. Oscillations occur initially, as tariffs are introduced in period one, and it takes

Figure 7.3: Zero and Ten Per Cent Discount

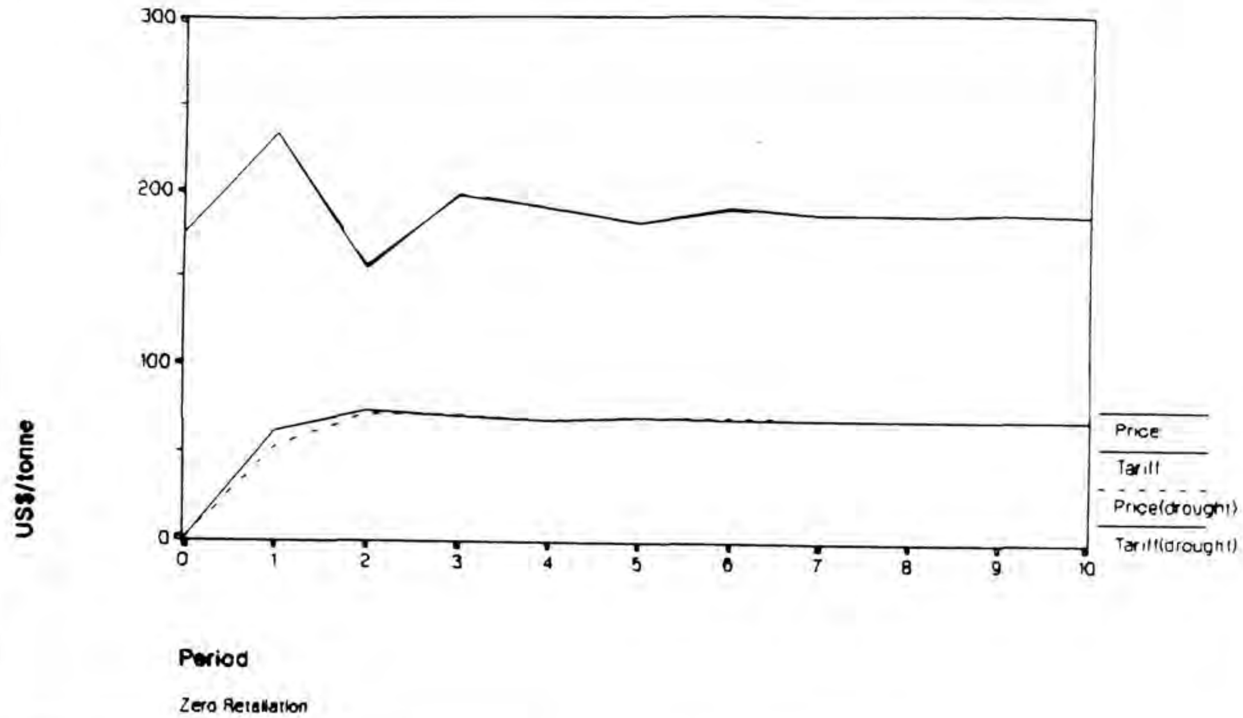


a number of periods for a new equilibrium to be established. Taxes increase markedly in the last period, as revenue is collected by the government, but producers have not had the time to change their production. If the oscillations emanating from each end meet, then convergence may not be attained. This is known as the turnpike problem, named in reference to the problem of deciding when to use a freeway (turnpike) as opposed to a local route. The distance to and from a freeway determines its use relative to a more direct but slower route. This implies that a four period horizon may be too short for the impact of policies to take full effect. Policymakers may be concerning themselves with disequilibrium analysis. The time horizon for the remaining analysis in this subsection, relating to discounting and drought, is ten years.

Alternative discount rates

The influence of discounting can be seen in Figure 7.3. In comparison to a zero rate, a real discount rate of 10 per cent per annum results in a rise in average world prices, but a fall in trade and global welfare. Taxes are significantly higher, and these are reflected in the world price. The discount rate is quite high, but it indicates the sensitivity of optimal tariff setting to discounting.

Figure 7.4: Impact of USA Drought



Drought

Next, the response to a supply side shock is assessed. Wheat production is assumed to be reduced in the USA by 20 per cent (of the free trade production level) in the first period only. A drought may cause such a change. Recall that the data relate to an average of the period 1978 to 1980. Furthermore, this model assumes no changes in stock levels. As can be seen in Figure 7.4, the first period's tariff is significantly reduced, from \$64 to \$55/t. However, the remaining taxes are very similar to the benchmark, although the effect of a drought is not completely eliminated until period nine. Because of the lower USA tax, world prices are in fact marginally lower. This demonstrates the stabilising effect of optimal tariffs, a result found by Karp and McCalla (1983).

7.3.4 The trade war solution

Thus far the single controller problem has been examined. Now assume that other countries do retaliate. The equilibrium obtained is Cournot-Nash, and it is found iteratively.

The Cournot-Nash trade war solution is presented in Table 7.2. Average tariffs, trade

Table 7.2: Cournot-Nash Tariffs, Trade and Welfare With Two-Period Lag: Ten-year Averages

Region	Tariff (US$/t)	Trade (mmt)	Welfare (US$m)
United States	-70	-28	21712
Canada	-38	-14	8000
Australia	-35	-14	6199
Argentina	-12	-4	6968
South Africa	-3	0	2599
EC	-4	-1	33111
Other Western Europe	0	1	8034
Japan	12	6	3094
Eastern Europe	9	4	3313
USSR	16	7	3936
China	15	7	2219
Brazil	8	4	4625
Central America & Other South America	12	6	5707
Egypt	9	4	2483
Other North Africa & Middle East	21	10	36611
Other Africa	5	3	1380
India	-2	0	20115
Other South Asia	1	1	6709
South East Asia	3	1	1067
East Asia	11	5	2659
Rest of World	8	4	1224

Average world price: US$190; Average trade flow: 62.1 mmt.

flows and welfare levels are calculated for each region assuming a zero discount rate, a coefficient of adjustment of -0.3 (a two-period lag) and a twenty year time horizon. All welfare weights are unity. Once again, negative tariffs reflect a domestic price below the world price (export taxes or import subsidies). Negative trade volume reflects net exports, and positive values denote net imports.

In comparison to the situation where the USA alone taxes its exports, average annual prices have risen marginally from $189.40 to $189.80, although the equilibrium price is $191. Average total trade flow has fallen from 63.6 to 62.1 mmt. Global welfare has also fallen, from $182091m to $181766m. The USA's taxes are somewhat reduced in the early periods, but are higher in the later periods. The average tax is the same as in the no-retaliation case, although it converges to \$68. A lower equilibrium tax is to be expected in the presence of retaliation. World price is less stable than in the no-retaliation scenario, with convergence taking a greater number of periods. This reflects the time lags each country experiences in responding to other countries' policy changes.

One-period lag

The Cournot-Nash solution for the one-period lag and a ten year horizon was also calculated, but the results are not shown. The average world price is \$212, reflecting much higher tariffs. Trade and welfare are reduced. The iterative process is much less stable, with large fluctuations in optimal tariffs. Four times as many iterations are required before convergence is obtained. In the 20 period model, convergence is not achieved at all. Because of this, less credence can be placed on the results of the one-period model. In the remaining analysis, the two-period lag is used.

Discounting, time horizons and drought

The impact of discounting on the trade war solution is similar to the no-retaliation case. Tariffs are raised quite significantly, but the effect on world price is not so pronounced, as importers are imposing tariffs which tend to have a downward effect on price. Prices are similar to those obtained for the zero-discounting case.

Shortening the time horizon for all countries also has similar effects as for the no-retaliation example. Prices fall, and trade and welfare rises. The existence of retaliation doesn't change the results.

Finally, consider the impact of a drought on the trade war. The discount rate is zero, the time horizon is ten years, and the adjustment coefficient is -0.3. Average tariffs, prices and welfare over the ten year period are essentially unchanged. However, the USA tariff in the first period is reduced by around US\$11. Adjustment tends to occur in tariffs rather than prices. In the free trade model, the drought leads to a price rise from US\$175 to US\$229. The price is US\$218 in the trade war case. Furthermore, most of the adjustment has occurred after only two or three periods. Without tariff changes, the effect of a supply shift is felt for about ten iterations. However, with adjustments in tariffs, the additional effect of the drought dissipates quite rapidly.

7.4 Dynamic Trade War with Welfare Weights

In this section, welfare weights are used to show how countries might react to a trade war situation. The results show what would happen if countries acted in a manner consistent with their behaviour in the reference period.

An updated data set is used in this section. Following presentation of the reference data, including tariffs, implicit welfare weights are estimated. The sensitivity of prices, trade and welfare distribution to the weights is calculated. The trade war solutions both with and without weights (that is, unitary weights) are shown. Finally, distributional effects over time are assessed.

Ideally, weights should be estimated for each period, as it is unreasonable to expect that they would remain stable over a number of years. For historical periods, this requires a significant amount of data. Here, for simplicity, static weights have been estimated for just one year. These are used throughout all periods in the dynamic model. While this procedure is not ideal, it is not clear how simultaneous multiperiod estimation of the weights would alter the results. The bias in the weights depends on the particular reference period. In the static model, weights were based on observations from the late seventies, a stable period. By contrast, the weights for the dynamic analysis are based on a period more representative of the high protective measures, and lower prices, of the 1980s.

7.5 The 1985-86 data set

In this section, the data pertain to the crop year 1985-86. These are the most recent, and are characterised by low prices and high protection coefficients. Thus, the calculated weights are more diverse than had data from 1980 been used. The disadvantage of this is that 1985-86 may be considered an unrepresentative year, resulting from unintended consequences of policies taken a number of years earlier. In spite of this problem, the more recent period is of sufficient interest to justify its analysis here. The unrepresentativeness should be borne in mind when drawing implications from the results.

The data are presented in Table 7.3. The quantity data were obtained from International Wheat Council statistics, as presented in IAC (1988). The elasticities are from Sarris and Freebairn (1983), and are short-run. They were presented in Table 5.1, but are reproduced in Table 7.3. The price data are from Pearce, Walker and Horridge (1988). The prices are the ratio of domestic to border prices, and reflect the (net) assistance provided to producers or consumers. For example, the value of 1.9 in Table 7.3 for USA producers indicates that the effect of the policies is equivalent to a domestic producer price 90 per cent higher than the world price. As such, the prices may not reflect prices actually received by producers or paid by consumers.

In this model, the world has been divided into eleven regions, including the five major exporters and importers, and the rest of the world, which acts as a free trader. This avoids the anomaly of having multicountry regions setting a joint tariff in a noncooperative model. The USSR, China and the Rest-of-World are treated as net trading entities, with supply specified at zero. All prices are in US$ terms. The world price is taken as $128/t, the US Gulf hard red winter wheat price. Trade volume in the period was 87.0 mmt. Under free trade, the equilibrium world price would be $158 and trade volume 71.9 mmt. The 1985-86 policies thus favoured consumers in those countries that purchased grain at the world price, and resulted in a significant increase in trade volume over the free trade level.

In the dynamic analysis, the real discount rate is set at five per cent. The adjustment coefficient ϵ is -0.3 for all countries for all time periods. The model is run over 20 periods. Extending the horizon has no effect on the initial optimal tariffs.

Table 7.3: Base Simulation Data 1985-86

Region	S (mmt)	D (mmt)	D - S (mmt)	P^s/P	P^d/P	Es	Ed
United States	66.0	28.5	-37.5	1.90	1.05	0.20	0.15
Canada	24.3	5.7	-18.6	1.25	1.20	0.17	0.10
EC	71.2	57.5	-13.7	1.80	1.55	0.35	0.20
Australia	16.2	3.0	-13.2	1.05	1.15	0.10	0.10
Argentina	8.7	4.7	-4.0	0.85	0.85	0.12	0.05
USSR	0.0	16.4	16.4	0.90	0.90	0.00	0.15
China	0.0	6.8	6.8	1.50	1.35	0.00	0.25
Japan	0.9	6.5	5.6	10.00	2.85	0.10	0.22
Brazil	4.2	6.7	2.5	1.56	1.00	0.15	0.12
Egypt	1.9	8.5	6.6	0.60	0.60	0.12	0.17
Rest of World	0.0	40.1	40.1	1.00	1.00	0.00	0.25

Source: Sarris and Freebairn, 1983; IAC 1988; Pearce *et al.* 1988.
S denotes production; D - consumption; D - S - net imports; P^s producer price; P^d consumer price; Es - supply elasticity; Ed - demand elasticity.
World price is US$128, and total trade volume 87.0 mmt.

7.5.1 Static Cournot-Nash solution and welfare weights

The static Cournot-Nash solution is shown in Table 7.4, along with the observed tariffs, and the implicit welfare weights that have been derived from equilibrium and actual tariffs. The world price is $163. Trade volume is reduced from the free trade level to 65.5 mmt, and global welfare is reduced by half a per cent. In comparison with free trade, exporters tend to gain from a trade war, whereas welfare is reduced in importing countries. Consumers benefit in exporting countries, because the export tax reduces domestic prices. In importing countries, the distribution of the gains and losses depends upon the size of the domestic tariff in comparison to the fall in world prices. If the world price fall is greater than the domestic tariff, consumers will gain at the expense of producers.

Observed tariffs are also shown in Table 7.4. These are derived from Table 7.3. The tariffs are quite different from the equilibrium levels, which are optimum, given the weights. The relationship between the equilibrium and observed tariffs is reflected in the weights. If both are the same, the weights are one. Domestic prices greater than the equilibrium result in producer weights in excess of one, and consumer weights less than one. For

Table 7.4: Cournot-Nash Equilibrium and Observed Tariffs, and Implicit Welfare Weights 1986

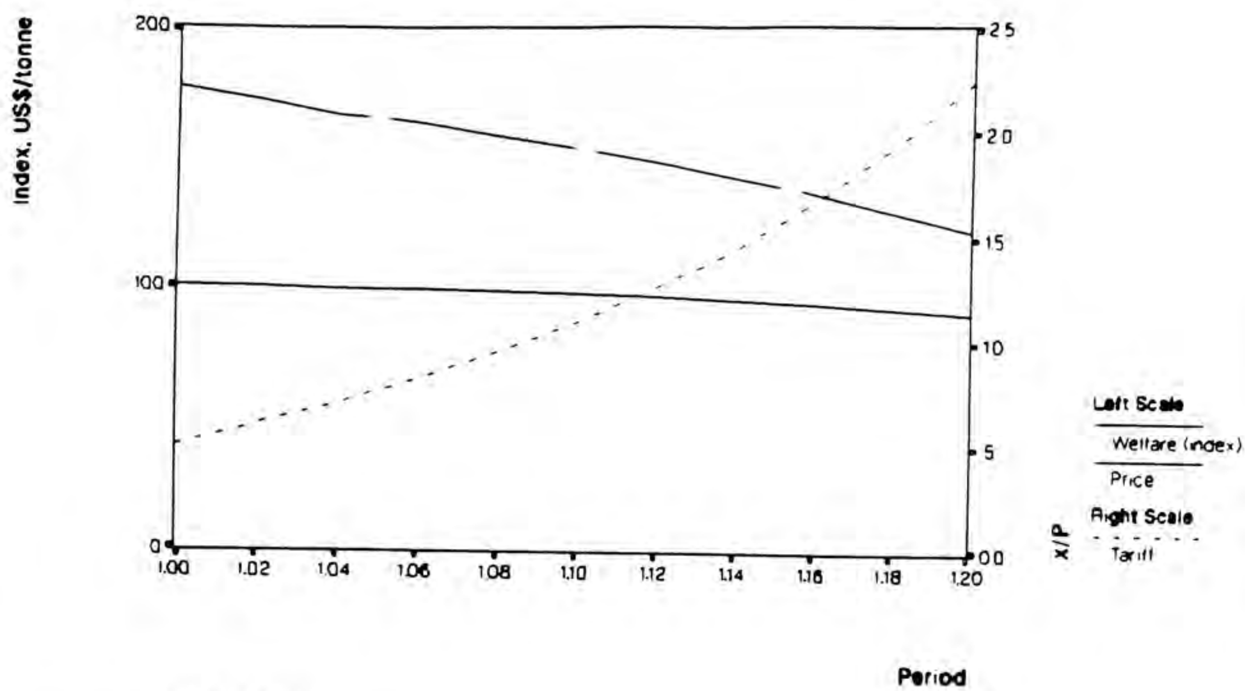
Region	x^d	x^s	$\bar{x}^d$	$\bar{x}^s$	w_c	w_p	w_g
	Equilibrium†		Observed		Estimated‡		
	(US$/t)	(US$/t)	(US$/t)	(US$/t)			
United States	-75	-75	6	115	0.868	1.153	0.979
Canada	-41	-41	26	32	0.944	1.068	0.988
EC	-10	-10	70	102	0.862	1.174	0.964
Australia	-30	-30	19	6	0.969	1.029	1.002
Argentina	-10	-10	-19	-19	1.007	0.990	1.002
USSR	34	0	-13	-13	1.000	1.000	1.000
China	15	0	45	64	1.000	1.000	1.000
Japan	14	14	237	1152	0.879	1.106	1.015
Brazil	5	5	0	72	0.987	1.031	0.982
Egypt	10	10	-51	-51	1.130	0.881	0.989
Rest of World	83	0	0	0	1.000	1.000	1.000

†These are equilibrium values assuming unitary weights.
‡Weights if observed tariffs were at their Cournot-Nash equilibrium levels.
Weights are assumed to be unity for the USSR, China and Rest of World.

example, the observed USA domestic prices exceed the equilibrium, hence producers are favoured by the policymaker at the expense of consumers. The government revenue weight below one indicates that less than the equilibrium amount of tax is collected. Weights have not been calculated for the net trading entities. These are assumed to be unity.

The estimated weights confirm expectations. Values are more extreme than those obtained from the 1978-79 to 1979-80 data set, and presented in Table 5.6. Wheat producers are supported in exporting countries (excluding Argentina in the reference year). The cost of this support is met largely by consumers, and by a reduction in export tax revenue, to a lesser extent. In the three importing countries for which weights are estimated, the pattern is less clear. Japanese taxpayers heavily subsidise local producers, and consumers pay a tariff on imported wheat. In spite of the high levels of producer protection, the government gains overall because of the low level of self-sufficiency. Brazilian policy favours producers, while Egypt maintains a typical third world food policy of subsidising consumers at the expense of producers and taxpayers.

Figure 7.5: Sensitivity to Welfare Weights



Source Table 7.5

7.5.2 Sensitivity to welfare weights

The estimated weights appear reasonably close to one, in spite of quite large price differentials. This has the important implication that slight changes in the policymakers' preferences can lead to substantial changes in tariffs, and hence in trade flows and in the distribution of surpluses. This is shown in Table 7.5 and in Figure 7.5. The data are USA taxes or subsidies, exports and welfare levels assuming retaliation does not occur. Values are derived from the dynamic model and, due to horizon problems, are averages of the first ten of the twenty periods arbitrary weight, and the remaining weights are equal to $(3 - Wp)/2$. A producer weight of 1.10 implies that a transfer of \$1.00 of resources to wheat producers is worth \$1.10 to society as a whole. A relatively small change in this valuation leads to substantial resource transfers. As the producer weight is increased, the tax that will maximise the weighted welfare function decreases, and eventually switches to a subsidy. As the tax falls, trade increases, but welfare, measured with the conventional unitary weights, decreases. The impact on the world price is shown in the final column. Average prices fall. The specification of the welfare function clearly has important implications for trade policy, both within the country setting the policy, and in other countries through the effect on the world price.

Table 7.5: Sensitivity to Welfare Weights: USA

Weight(Wp)	Tariff†	Trade	Welfare	World Price
	$P^{s,d}/P$	mmt	Index	US$/t
1.00	0.49	-28.5	100	177
1.02	0.59	-32.2	100	173
1.04	0.69	-33.7	99.9	167
1.06	0.81	-35.0	99.6	164
1.08	0.94	-36.4	99.2	159
1.10	1.09	-37.9	98.6	154
1.12	1.26	-39.5	97.7	149
1.14	1.44	-41.1	96.6	143
1.16	1.67	-42.9	95.1	137
1.18	1.93	-44.8	93.2	130
1.20	2.24	-46.8	90.9	123

Tariffs, trade and welfare refer to the USA.
†Tariffs are expressed here as the ratio of domestic to world price.
Weights on consumer surplus and tariff revenue are assumed to be equal for these calculations.

7.5.3 Dynamic trade war solution

The dynamic Cournot-Nash trade war solutions[8] with unitary and estimated welfare weights are shown in Table 7.6. As tariffs are sensitive to the weights chosen, what is the outcome of a trade war if all countries follow policies aimed at maximising a weighted welfare function, and policymakers assume that other countries follow a similar strategy? With weighted functions, the four main exporters subsidise their producers to a considerable extent. Only Argentina applies an export tax. All importers except Egypt impose a tariff. These tariffs do not have as significant an effect on world prices as the exporters' subsidies, so the overall impact of the trade war is to increase trade flow from 69.7 mmt to 81.7 mmt, and world price is $77 compared with $189 in the unweighted Cournot-Nash solution. The welfare (in conventional unweighted terms) has fallen for all exporters, but has risen for all importers. Global welfare has risen slightly, illustrating that the weighted Cournot-Nash equilibrium is closer to free trade than the unweighted equilibrium.

[8] In the dynamic solutions, producer and consumer prices are constrained to be the same. This simplifies the analysis, as only one control variable needs to be estimated. However, the weights are derived from the static two-price model.

Table 7.6: Cournot-Nash Tariffs, Trade and Welfare: Ten-year Averages

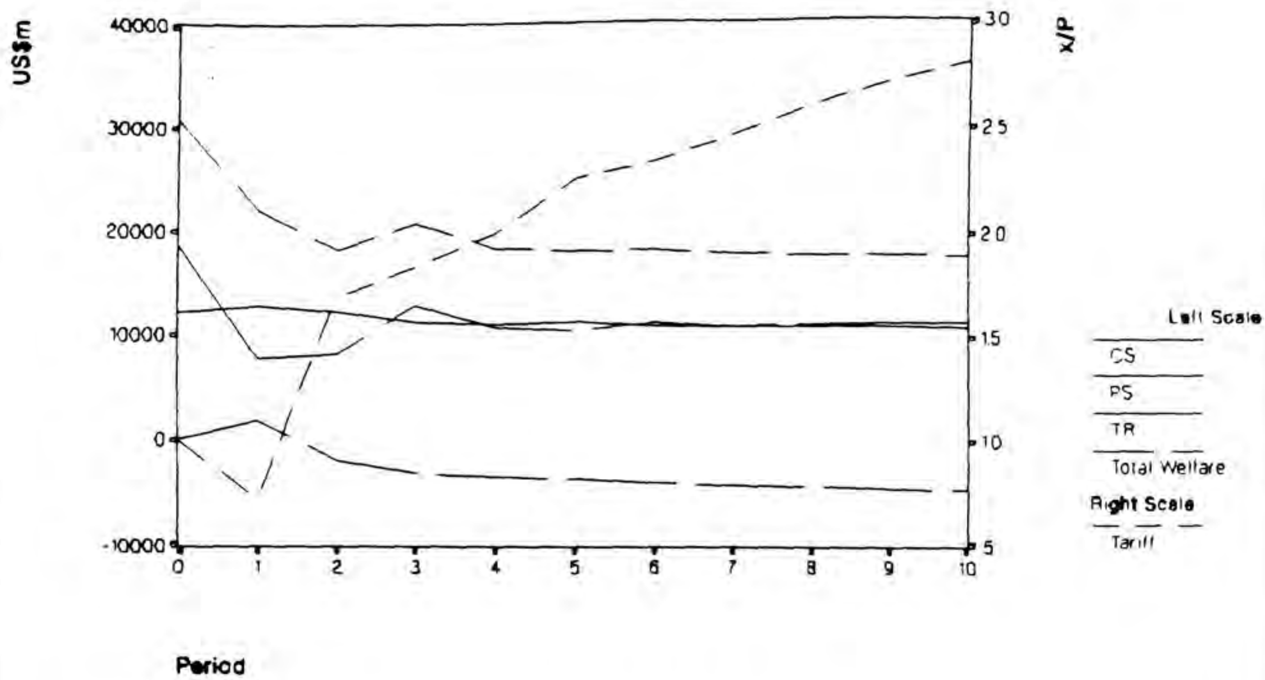
Region	Estimated Weights			Unitary Weights		
	Tariff (US$/t)	Trade (mmt)	Welfare (US$m)	Tariff (US$/t)	Trade (mmt)	Welfare (US$m)
United States	89	-35.5	21994	-93	-29.0	24869
Canada	73	-18.8	7868	-58	-17.9	9539
EC	113	-10.5	43717	-21	-4.8	44575
Australia	36	-13.2	4542	-45	-13.3	5742
Argentina	-8	-3.9	6735	-21	-4.7	7113
USSR	50	15.8	7204	37	14.2	5699
China	23	7.3	3168	17	6.5	2488
Japan	263	5.8	7946	17	6.3	7455
Brazil	34	2.7	4625	3	2.2	4366
Egypt	-54	7.1	2129	9	4.1	1646
Rest of World	0	42	12649	0	35.5	8892
TOTAL		69.7			81.9	

Average world price: $189 (unit weights); $77 (estimated weights);
discount rate: 5 per cent; coefficient of adjustment (ϵ): -0.3.

7.5.4 Dynamic distributional effects

As a country enters into a trade war, the distributional effects alter from period to period, due to the lagged response of producers. These effects are shown for the USA in Table 7.7 and in Figure 7.6. The data in Table 7.7 are derived from the solution presented in Table 7.6 in which estimated weights are used. Period 0 shows the free trade solution. The USA applies a tax in the first period, when there is no output response, but producers are increasingly favoured in the remaining periods, as the trade war becomes increasingly entrenched. As a result, world prices rise then gradually fall. Consumer surplus rises initially, but then falls over the time horizon. By contrast, producer surplus declines markedly initially, but improves as the increasing subsidy outweighs the falling world price. As the subsidy leads to increased production and exports, the government budgetary cost increases faster than the subsidy. The overall effect is falling welfare for the USA as a whole, as the additional budgetary cost swamps the changes in producer and consumer surplus. The welfare effects are quite substantial. Average welfare for the ten year period of the trade war is reduced by $2854m because the USA, and other countries, are optimising

Figure 7.6: USA Distributional Effects



Source Table 7.7

a weighted rather than unweighted welfare function.

7.6 Implications

The results presented in this chapter, for the dynamic analysis, confirm those obtained from the static model. Taxes are in general optimal for exporters, and tariffs are optimal for importers. Even with the long-run elasticities, these taxes and tariffs are quite substantial.

Apart from confirming tariff-setting behaviour obtained from the static model, of what significance is the dynamic model? First, the lag structure has an important influence on trade policies and prices. Average levels are not markedly different, but the direction of movement and stability is influenced quite noticeably by the speed of adjustment, at least over the range of values examined here. This illustrates the need to correctly specify the dynamics of the model.

The most notable result from the analysis is that changes in supply, the discount rate or the perceived planning horizon are accommodated mainly by changes in trade policy, rather than in world price. Trade policies serve, in this model at least, to absorb

Table 7.7: USA Distributional Effects of Trade Policies‡

Period	Tariff†	World Price	Consumer Surplus	Producer Surplus	Government Revenue	Welfare
	$(P^{s,d}/P)$	(US$/t)	(US$m)	(US$m)	(US$m)	(US$m)
0	1.00	158	12096	18759	0	30854
1	0.72	188	12722	7670	1717	22109
2	1.69	90	12269	8108	-1974	18402
3	1.84	103	11222	12878	-3144	20957
4	2.00	96	11187	10876	-3470	18592
5	2.26	81	11411	10721	-3713	18420
6	2.35	82	11151	11481	-4038	18594
7	2.47	78	11145	11206	-4218	18133
8	2.61	74	11135	11315	-4383	18067
9	2.72	72	11073	11464	-4555	17982
10	2.81	70	11049	11487	-4705	17831

‡Trade policies are the Cournot-Nash equilibrium values with weighted welfare functions for all countries.
†Tariffs are expressed here as the ratio of domestic to world price.

shocks. This suggests that national welfare is enhanced by absorbing changes in the world price, rather than insulating domestic markets from world price movements. Ironically, such an optimal response doesn't appear to be the case in practice. This implies that policymakers place unequal weights on the welfare function, or attach great importance to domestic stability, an aspect of policy that has been ignored in this analysis and in many other analyses.

These results highlight the significance of the perceived time horizon. The time horizon does affect the initial tariffs if it is less than five or six years. This suggest that policymakers may be unduly influenced by short-term events, such as elections. The influence of the time horizon depends on the discount rate. High rates reduce the instability that occurs at the end of the time horizon.

In these results, export subsidies were not explained by the differing time horizons, as Karp and McCalla (1983) found in the corn market. This may be due to the short-run nature of the elasticities, which generate large tariffs and taxes. The longer lag also adds stability to the model. This illustrates once again the importance of correctly specifying the lags, both in production and in policymaking.

In the base period characterised by high protection level, government interference was substantial, yet policies were quite different from the Cournot-Nash policies (even in the absence of retaliation) of export taxes for exporters with some ability to influence the world price, and import tariffs for importers. Clearly, policymakers are not optimising an unweighted welfare function. The implication of this is that when considering how other countries may retaliate, each country must take into account its rivals' preferences regarding the allocation of resources to the various groups. There is little point in making concessions in a particular area, such as assistance to the manufacturing sector, if other countries in the bargaining process attach a low value to such concessions. In predicting how rivals will respond, a knowledge of the implicit welfare weights is of great importance.

Although it is important to know how other countries will react, the welfare weights should not be seen as a justification for various policies. Weights ought not be used in a normative sense, as a justification for the status quo. In fact, if tariffs are set so as to maximise a weighted welfare function, resource allocation is by no means Pareto efficient.

What do these results imply for policy? Even with retaliation, tariffs and taxes are welfare maximising in some countries. There is an incentive to raise barriers surreptitiously to minimise the probability of detection and the consequent retaliation. Certainly, much of the present discussion concerning trade liberalisation is centered around the measurement of trade barriers. The importance of this is illustrated here. Each country has an incentive to 'cheat', and means of detection are important if movements towards trade liberalisation are to be successful.

Australia's approach to trade policy can be analysed in game-theoretic terms. The espousal of free trade is an attempt to push other players towards a cooperative outcome. This persuasion is enhanced by membership of the Cairns Group. Large groups carry greater weight, as they have the possibility of exercising the market power that comes with market share. The benefits of forming a coalition with other traders on the same side of the market are considerable. However, the difficulties in maintaining the necessary cohesion are also considerable. Informing other countries of the cost of their policies to themselves (Bureau of Agricultural Economics (BAE) 1985) can be seen as an attempt to alter the weights that overseas policymakers attach to their welfare functions.

Chapter 8

Trade Games with Competitive Storage

8.1 Introduction

The models described thus far do not include storage. The rationale for storage in a deterministic model results not from stochastic shocks, but from the price variation induced by the tariffs, or by autonomous changes in supply or demand. Given fluctuating prices, it is reasonable that private, competitive storage plays some role in smoothing out those price fluctuations. Just as consumers and producers respond to price changes, so would stockholders, in an effort to maximise their speculative gains.

The purpose of this chapter [1] is to incorporate private, competitive storage into a dynamic game model. Of interest is the use of storage as a strategic policy. What is the optimal level of storage, and what are the effects on domestic and world price levels and stability? Does the opportunity to store alter trade barriers, and lead to a smoothing of world and domestic price fluctuations? How is market power affected by the holding of stocks, and given this, what is the importance of storage costs in determining which

[1] Some of the material in this chapter appeared in Vanzetti and Kennedy (1989).

countries hold stocks?

In the previous chapter, the dynamic game model required the use of dynamic programming to provide an analytic solution for the optimal set of tariffs over time. Riccati equations were used to update the welfare matrix each period. The advantage of this procedure is that the so-called 'curse of dimensionality' is overcome. There is no practical constraint on the number of time periods or regions that can be included in the model. A limitation of the procedure is that it requires that the state transformation equations be equalities. If stocks are to be included in the model, it is necessary that they not fall below zero[2]. Thus, a different approach is necessary. In this chapter, a multiperiod, quadratic programming trade model is presented. This is used to find the welfare maximising levels of tariffs, stocks, production, consumption and price for each country, for any given level of tariffs and stocks in other countries. An iterative procedure is then used to find the game-theoretic Cournot-Nash equilibrium.

In the next section, the stockholding literature as it applies to trade is examined. The QP model is described in Section 3, and applied to the international wheat market in Section 4. Implications and conclusions are presented in the final section.

8.2 Storage and Trade

In this section the role of storage in stabilising prices and increasing welfare is reviewed. Stabilisation is then related to the international market, where instability may be induced (or indeed, reduced) by trade policies, as well as by stochastic shocks. Finally, the relationship between storage and market power is assessed. Studies which examine these areas are reviewed.

[2]This requirement ignores the possibility of using futures markets to sell a crop that has not yet been produced.

8.2.1 Stabilisation

The welfare effects of stabilisation are well known. Massell (1969) showed that with linear supply and demand curves and stochastic, additive shift terms, complete price stabilisation leads to an increase in the expected value of welfare. Massell synthesised the work of Waugh (1944), who concluded that consumers gain from unstable supply, and Oi (1961), who deduced that producers gain from instability caused by shifts in demand. Gains can be made, it appeared, by generating instability, a counter-intuitive result indeed. Massell showed that 'bootstrapping' in this way does not result in gains if returns to both sides of the market (consumer and producer surpluses) are considered.

Massell's rather limited analysis was extended to include nonlinear demand and supply and multiplicative risk (Turnovsky 1976). Newbery and Stiglitz (1981) provided more general solutions involving lagged or rational expectations, and risk aversion. These contributions indicate that generalisations are difficult to make. Results depends crucially on the assumptions made concerning the curvature of the demand and supply curve, risk aversion, the formation of expected prices, the form of the disturbance, the uncertainty of random prices, and the response of private stockholders to public intervention. Nonetheless, Newbery and Stiglitz found, as did Scandizzo, Hazell and Anderson (1984), that much of the gains from stabilisation could be attributed to the removal of forecasting errors, because the cost of instability varies directly with producers' price forecasts. More accurate forecasts would remove much of the need for stabilisation by means of stockholding (Scandizzo et al., p. 77).

Now consider price stabilisation in international trade. It follows from the work of Oi that exporters gain and importers lose from perfect stabilisation when supply is unstable (assuming linear supply and demand schedules and additive disturbances). Conversely, exporters lose and importers gain from stabilisation when demand fluctuations are the source of instability. Regardless of the source, the net effect of stabilisation is a global increase in welfare.

8.2.2 Trade as a substitute for storage

Of course, variations in prices can be accommodated not only by a change in stocks, but also by a change in trade. A given domestic price increase can be avoided by a reduction in stocks or an increase in imports. Trade policies affect trade flows, so what is the relationship between stocks and trade policy? An importer can reduce tariffs in times of shortage, thus increasing imports and reducing the need to rely on stocks. Since a given shortage can be met by changes in tariffs or stocks, any tariff can be expressed in terms of an inventory equivalent. Grennes, Johnson and Thursby (1978) show what inventory level would have been required to eliminate the price rises of 1973-74. Given the 1972-73 policies (before the price rise), a release of 7.2 per cent of stocks would have stabilised USA prices. Actual policies in 1973-74 increased demand for US wheat such that a 12 per cent reduction in stocks was required to maintain stable prices. Insulating trade policies of other countries shifted the burden of adjustment onto the USA. The trade policies decreased the effectiveness of the USA stockholding policy. The corollary here is that if trade policies were used to stabilise the world price, there would be less need to hold stocks.

Bigman (1985) demonstrates the effectiveness of free trade compared with other stabilisation policies (such as buffer stocks, minium price support, government procurement and guaranteed income). The stabilising effect of an open economy considerably reduces both the need for and cost of various stabilisation programs. Of course, the relative effectiveness of stocks and free trade depend upon the supply and demand parameters, the degree of risk aversion, the cost of storage and other factors. An important consideration is that other countries may insulate their domestic economies, leaving free traders prone to wide fluctuations in price.

Zwart and Meilke (1979) examine the relationship between domestic policies and international storage policies. They are concerned to show what sort of storage policy would offset the domestic policies which destabilised the world price. They define a storage response parameter which determines the degree of stability in price. This parameter depends on the demand and supply responses in the importing countries, and the responsiveness of domestic prices to world prices (p. 438). The simple relationship between storage and stability is dependent on the linearity of their model. Their model shows that if the stock level is sufficiently high to minimise the probability of completely depleting stocks, almost any desired level of stability can be attained.

Zwart and Meilke also demonstrate that stability can be attained by varying domestic policies to counter stochastic shocks. However, they are not able to conclude whether such measures are more appropriate than buffer stock policies, the result depending upon the particular costs of domestic instability compared with the costs of financing the buffer stocks.

Shei and Thompson (1977) examine the relationship between domestic policies and price stability, utilising a quadratic programming model. They come to the now familiar conclusion that domestic policies, which insulate domestic markets, are the source of much instability in the world market. Certainly, it appears that the commodity price boom of 1972 to 1974 could have been largely avoided had all countries, particularly the EC and the USSR, responded to the relatively modest production shortfall.

Newbery (1984) argues that stabilisation provides larger benefits in the presence of trade distortions than in their absence. First, prices are inherently less stable with distortions. However, the type of distortion (tariffs or quotas) significantly affects the possible benefits, depending on whether the degree of distortion changes with the variability in price. Second, increased stability may lead to an increase in supply from risk averse producers, resulting in additional benefits.

8.2.3 Storage and market power

Newbery addresses the important point concerning storage and market power. A monopolist facing a stable linear demand curve will store more than a competitive market with the same average supply. This enables the monopolist to exploit the consumers more effectively (p. 273). However, the monopolist may store less than the competitive amount if the demand curve has a constant elasticity (depending upon the curvature). Consumers can counter this monopoly power by carrying their own stocks, and prices will be no less stable than in a perfectly competitive environment.

Nichols and Zeckhauser (1977) examined stockpiling aimed at suppressing rather than smoothing prices. Consumers build up stocks in early periods to influence a monopolist producer to lower prices in later periods. Here, supply conditions are determined not by chance (that is, stochastic disturbances) but by a producer or producer cartel attempting to maximise profits. In fact, both parties gain from the consumer stockpile, as the countervailing power reduces deadweight efficiency losses. The distribution of the gains depends on the time horizon, with consumers becoming relatively better off as the horizon increases. The outcome of this game depends very much on the assumptions regarding supply characteristics somewhat peculiar to depletable resources, but serves to illustrate the role of stockholding in offsetting market power.

From the literature it can be concluded that instability due to stochastic shocks can be modified by either stockholding or by free trade. Given that the correlation between shocks across countries is low, free trade appears to be the most suitable means of stabilisation. However, many countries have chosen trade policies which insulate the domestic markets, thus preventing the international trading system from accommodating the instability.

8.2.4 Limitations

A limitation of these models (excepting Nichols and Zeckhauser) is that stockholding policy is not aimed at optimising a particular objective, such as maximum welfare or utility. The models show the trade-offs between stockholding and alternative trade policies in achieving a given stability. Price stabilisation is not weighed up against other objectives. Furthermore, no account is taken of market power in these models, nor of the possibility that rival traders may retaliate. In the following section, a trade model, in which the welfare maximising levels of stocks and tariffs are simultaneously determined, is derived. Rival traders' behaviour is also taken into account. The assumption of linearity is retained and there are no stochastic shocks. Stocks are held in response to price fluctuations induced by policy changes.

8.3 A Multiperiod QP Model With Tariffs and Storage

The analysis in this section utilises the simple, dynamic, linear trade model described in Chapter 7. A quadratic programming procedure is used to solve simultaneously for the welfare-maximising levels of tariffs (or subsidies or taxes), stocks, production, consumption and world price.

One point which needs elaboration is the reason for holding stocks in a deterministic model. As there is no uncertainty, stockholding is required only to smooth out price fluctuations occurring for other reasons. One such reason is non-random demand shifts, due to autonomous growth in demand. The second reason is changes in world prices due to changes in tariffs.

Consider the model presented in Chapter 7. The assumptions made here are the same, except that stocks may be held. Trade taxes are set so as to maximise a welfare function subject to world price and the taxes and stocks set by all other countries. The welfare function for each country consists of the sum of discounted returns, including the costs and speculative profits from storage, accruing to the different groups over a finite number of years. In contrast to previous chapters, there are no weights on the welfare functions. The demand, supply and price expectations equation are as in Chapter 7, and will not be repeated here. However, two additional arbitrage equations are required.

Stocks are held if the price differential between periods is greater than the cost of carrying the stocks. The arbitrage equation can be represented by complementary inequalities

$$\begin{aligned} P_t + k &= \psi P_{t+1} \quad if \quad I_t \geq 0 \\ P_t + k &\geq \psi P_{t+1} \quad if \quad I_t = 0 \end{aligned} \tag{8.1}$$

where ψ is an appropriate real discount factor, k is the cost of storage, excluding interest, and I_t refers to stocks carried forward from period $t-1$ to period t. These inequalities imply non-negativity of stocks. If the cost of buying and holding stocks exceeds the discounted price in the selling period, no stocks will be held. Speculators will continue to store until the profit is driven down to zero. Where storage is not costless, welfare maximisation occurs at less then complete stabilisation. The price change between periods will, however, be no greater than the cost of carrying stock.

In each period, the excess of demand over supply must be equal to imports plus the change in stocks. Across all countries, the market clearing equilibrium condition requires that

$$\Sigma_{i=1}^{n}(D_{it} - S_{it}) + \Sigma_{i=1}^{n} I_{it} - \Sigma_{i=1}^{n} I_{it-1} = 0. \tag{8.2}$$

The market clearing free trade price is

$$P_t^f = \frac{1}{\Sigma_{i=1}^{n}\beta_i}[\Sigma_{i=1}^{n}(\alpha_i - \gamma_i) - \Sigma_{i=1}^{n}\delta_i(1+\epsilon_i)P_{t-1} - \Sigma_{i=1}^{n}\delta_i\epsilon_i P_{t-2} + \Sigma_{i=1}^{n} I_{it} - \Sigma_{i=1}^{n} I_{it-1}]. \tag{8.3}$$

With tariffs, the market clearing world price becomes

$$P_t = P_t^f - \frac{\Sigma_{i=1}^{n}(\beta_i x_{it} + \delta_i x_{it-1})}{\Sigma_{i=1}^{n}\beta_i}. \tag{8.4}$$

Once the world price and all tariffs and stocks are determined, welfare can be calculated. The composition of welfare in shown in Figure 8.1. If an importer desires to increase its level of storage, it must purchase the amount labelled 'cost'. Purchases are made at the world price, Pw, and the government collects tariff revenue on the imported stocks. Welfare is consumer and producer surplus, plus tariff revenue and the net gains from storage. The stockholder makes a gross profit by selling the amount stored at some price higher than P at a later date. The gross profit must cover the cost of carrying the stock from the time of purchase to resale.

The total welfare function to be maximised for country i over the time horizon is

$$W_i = \Sigma_{t=1}^{T}\psi^t W_{it}. \tag{8.5}$$

In each period,

$$W_{it} = CS_{it} + PS_{it} + TR_{it} + NSG_{it} \tag{8.6}$$

with

$$CS_{it} = \frac{D_{it}^2}{2\beta_{it}}, \tag{8.7}$$

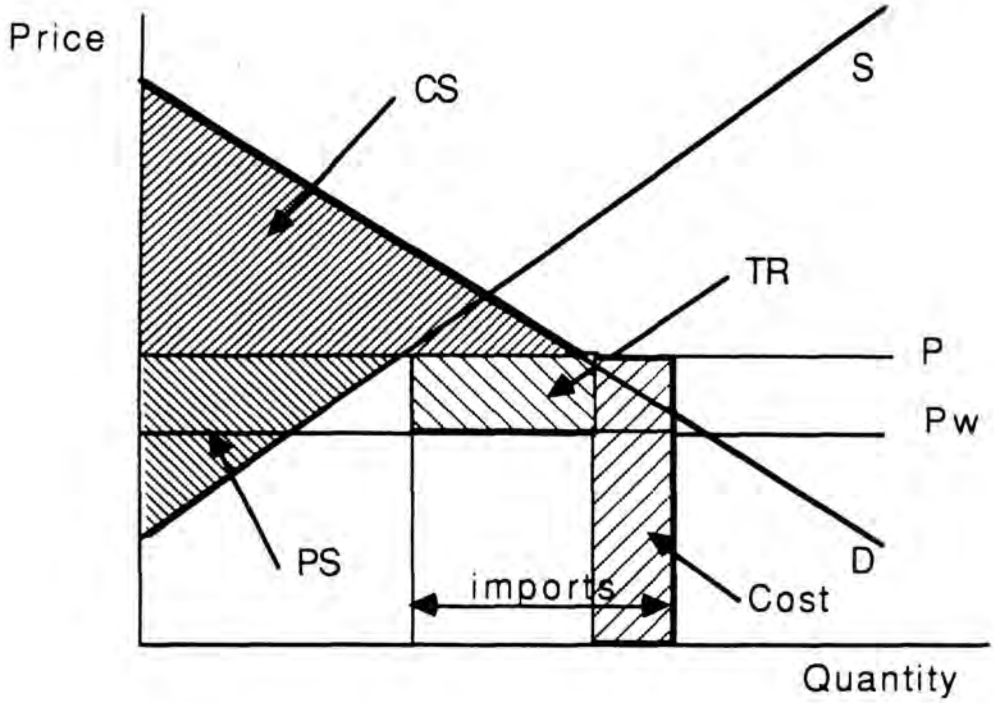


Figure 8.1: Impact of Storage

$$
\begin{aligned}
PS_{it} &= \frac{S_{it}^2 - \gamma_{it}^2}{2\delta_{it}} + S_{it}(P_t + x_{it} - P_t^e - x_{it-1}), && (8.8)\\
TR_{it} &= (D_{it} - S_{it})x_{it}, && (8.9)\\
NSG_{it} &= I_t(P_t - P_{t-1}) - k_t I_t. && (8.10)
\end{aligned}
$$

CS_{it}, PS_{it}, TR_{it} and NSG_{it} refer to consumer surplus, producer surplus, tariff revenue and net storage gain respectively. The surplus measured by PS_{it} is actual, rather than anticipated, surplus. Producers expect to receive price P_t^e, but actually receive P_t. D_{it} and S_{it} now depend on x_{jt} and x_{jt-1} for all j. The storage costs includes profits made on the sale of the stock at a price higher than the purchase price. Stockholders will increase their holdings up to a point where the cost is just equal to the price differential between the periods. With competitive, private storage, stockholders do not make excess profits. Normal profits are included in the cost function.

The welfare function can be expressed in matrix form as

$$W_{it} = p_{it}' y_{it} + \frac{1}{2} y_{it}' K_{it} y_{it} \qquad (8.11)$$

where p_i is an n vector of linear coefficients, y_i is an n vector of decision variables, and K_i

a negative semi-definite nxn matrix of quadratic coefficients. (As in Chapter 7, the off-diagonal terms in K_i are the coefficients of the multiplicative terms in the welfare function, and K_i is symmetric.)

The welfare function is maximised subject to the constraints implied by the demand, supply and market clearance equations, given in Chapter 7.

$$Ay = b \tag{8.12}$$

where A is a matrix of constraint coefficients, and b a vector of constraints (in this case, the demand and supply intercept terms, and stock levels). Assuming, for illustrative purposes, a two region by three period model, the various matrices can be represented as shown.

The vector of constants, b_i, shows the supply and demand intercept terms. The supply intercept terms in the first two periods are adjusted to account for lagged prices. Tariffs and stocks are solved for one country at a time. For the focus country, the intercepts are set at their initial (free trade) values, represented here as α_i' and γ_i'. The tariffs for other countries are included in the constant vector as shown. Stocks are included by summing across all of the non-focus countries, for each time period.

The variables in the solution vector y_i are demand and supply for each country in each period, stocks held in the focus country, world prices, and tariffs or subsidies in the focus country for each period. The x_t^e variables are the negative of x_t, and are included in order to provide for export taxes or import subsidies. This allows for the programming requirement that all decision variables be nonnegative.

The p_i vector contains the initial price term, which influences supply in the first two periods, and the storage cost coefficients.

$$
K_i = \begin{bmatrix}
\frac{1}{\beta_i} & & & & & & \cdots & & & & & & 1 & & & -1 & & \\
& \frac{1}{\delta_i} & & & & & \cdots & & & 1 & & & & & & & & \\
& & \frac{\psi}{\beta_i} & & & & \cdots & & & & & & & \psi & & & -\psi & \\
& & & \frac{\psi}{\delta_i} & & & \cdots & & & -\psi(1+\epsilon) & \psi & & -\psi & & & \psi & & \\
& & & & \frac{\psi^2}{\beta_i} & & \cdots & & & & & & & & \psi^2 & & & -\psi^2 \\
& & & & & \frac{\psi^2}{\delta_i} & \cdots & & & \psi^2\epsilon & -\psi^2(1+\epsilon) & \psi^2 & & -\psi^2 & & & \psi^2 & \\
\vdots & & & & & & \vdots & & & & & & & & & & & \\
& & & & & & & & & -\psi & \psi^2 & & & & & & & \\
& & & & & & & & & & -\psi^2 & \psi^3 & & & & & & \\
& 1 & & -\psi(1+\epsilon) & & \psi^2\epsilon & \cdots & -\psi & & & & & & & & & & \\
& & & \psi & & -\psi^2(1+\epsilon) & \cdots & \psi^2 & -\psi^2 & & & & & & & & & \\
& & & & & \psi^2 & \cdots & & \psi^3 & & & & & & & & & \\
1 & & & -\psi & & & & & & & & & & & & & & \\
& & \psi & & & -\psi^2 & & & & & & & & & & & & \\
& & & & \psi^2 & & & & & & & & & & & & & \\
-1 & & & \psi & & & & & & & & & & & & & & \\
& & -\psi & & & \psi^2 & & & & & & & & & & & & \\
& & & & -\psi^2 & & & & & & & & & & & & &
\end{bmatrix}_{(n x n)}
$$

$$
A_i = \begin{bmatrix}
1 & & & & & & & & & & & & \beta_1 & & & & \beta_1 & & & & -\beta_1 & & & \\
& 1 & & & & & & & & & & & & & & & & & & & & & & \\
& & 1 & & & & & & & & & & & & & & & & & & & & & \\
& & & 1 & & & & & & & & & & & \beta_1 & & & & \beta_1 & & & & -\beta_1 & \\
& & & & 1 & & & & & & & & -\delta_1(1+\epsilon) & & & & -\delta_1(1+\epsilon) & & & & -\delta_1(1+\epsilon) & & & \\
& & & & & 1 & & & & & & & & & & \beta_1 & & & & \beta_1 & & & & -\beta_1 \\
& & & & & & 1 & & & & & & \epsilon\delta_1 & -\delta_1(1+\epsilon) & & & \epsilon\delta_1 & -\delta_1(1+\epsilon) & & & \epsilon\delta_1 & -\delta_1(1+\epsilon) & & \\
& & & & & & & 1 & & & & & \beta_2 & & & & & & & & & & & \\
& & & & & & & & 1 & & & & & & \beta_2 & & & & & & & & & \\
& & & & & & & & & 1 & & & -\delta_2(1+\epsilon) & & & & & & & & & & & \\
& & & & & & & & & & 1 & & & & & \beta_2 & & & & & & & & \\
& & & & & & & & & & & 1 & \epsilon\delta_2 & -\delta_2(1+\epsilon) & & & & & & & & & & \\
-1 & 1 & & & & & -1 & 1 & & & & & -1 & & & & & & & & & & & \\
& & -1 & 1 & & & & & -1 & 1 & & & 1 & -1 & & & & & & & & & & \\
& & & & -1 & 1 & & & & & -1 & 1 & & 1 & & & & & & & & & &
\end{bmatrix}_{(m x n)}
$$

$$y_i = \begin{bmatrix} D_{11} \\ S_{11} \\ D_{12} \\ S_{12} \\ D_{13} \\ S_{13} \\ D_{21} \\ S_{21} \\ D_{22} \\ S_{22} \\ D_{23} \\ S_{23} \\ I_{11} \\ I_{12} \\ P_1 \\ P_2 \\ P_3 \\ x_{11} \\ x_{12} \\ x_{13} \\ x^e_{11} \\ x^e_{12} \\ x^e_{13} \end{bmatrix}_{(nx1)} \quad p_i = \begin{bmatrix} 0 \\ -P_0 \\ 0 \\ \epsilon P_0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ -\psi k \\ -\psi^2 k \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}_{(nx1)} \quad b_i = \begin{bmatrix} \alpha_{11} & = & \alpha'_{11} \\ \gamma_1 & = & \gamma'_1 + \delta_1 P_0 \\ \alpha_{12} & = & \alpha'_{12} \\ \gamma_1 & = & \gamma'_1 - \delta_1 \epsilon P_0 \\ \alpha_{13} & = & \alpha'_{13} \\ \gamma_1 & = & \gamma'_1 \\ \alpha_{21} & = & \alpha'_{21} - \beta_2 x_{21} \\ \gamma_2 & = & \gamma'_2 + \delta_2 P_0 \\ \alpha_{22} & = & \alpha'_{22} - \beta_2 x_{22} \\ \gamma_2 & = & \gamma'_2 - \delta_2 \epsilon P_0 + \delta_2 x_{21} \\ \alpha_{23} & = & \alpha'_{23} - \beta_2 x_{23} \\ \gamma_2 & = & \gamma'_2 - \delta_2 x_{22} \\ -I_{21} & & \\ -I_{22} & & \end{bmatrix}_{(mx1)}$$

The matrices shown here relate to a solution for country 1. They have to be adjusted when country 2 is the focus country.

The programming problem is thus

$$\begin{aligned} Max \;\; W_i &= p'y + \frac{1}{2}y'Ky && (8.13) \\ s.t. \;\; Ay &= b && (8.14) \\ y &\geq 0. && (8.15) \end{aligned}$$

The solution to the maximisation problem shows the optimal combination of tariffs and stocks for a given set of tariffs and stocks in other countries. This provides a solution if rival countries do not respond to a policy change. However, if rivals do respond, and a trade war occurs, it is necessary to take this into account.

The dynamic Cournot-Nash equilibrium is obtained by an iterative procedure. First, the optimal policy over the specified time horizon is found for country 1, assuming all other countries have zero tariffs. This implies that P_0 is the free trade price for the first iteration. Next, country 2's optimal tariffs are found taking into account country 1's tariffs and stocks. This is done by updating the b matrix as indicated. Tariffs and stocks are successively found for all countries with previous solution values incorporated. The procedure is continued until convergence is obtained. Convergence is hastened by updating the constraint vector following each individual country's solution, rather than at the completion of each iteration. An example of this procedure is given in the next section.

8.4 A World Wheat Model with Storage

The analysis developed here can be suitably applied to the international wheat market. Wheat can be stored at reasonable cost, and market power exists, at least on the supply side.

8.4.1 The data

The data used here are the same as those used in the final section of Chapter 7, that is, the 1985-86 data. In this storage model, the world has been divided into the USA, the EC, Japan and the rest of the world, a competitive fringe, which does not set tariffs or store grain, but responds to the world price in both production and consumption. In this respect, this differs from the previous data set used, in which the Rest of World was treated as a net trading entity. This change reflects the greater number of countries which make up the Rest of World. This means that the results for individual country tariffs

Table 8.1: Base Simulation Data 1985-86

Region	D	S	D - S	Es	Ed
	(mmt)	(mmt)	(mmt)		
United States	28.50	66.00	-37.50	0.20	0.15
EC	57.50	71.20	-13.70	0.35	0.20
Japan	6.50	0.90	5.60	0.10	0.22
Rest of World	87.20	55.30	31.90	0.30	0.50

Source: Industries Assistance Commission, 1988 and Sarris and Freebairn, 1983.
S denotes production; D - consumption; D - S - net imports;
Es - supply elasticity; Ed - demand elasticity.
World price is US$128.00.

are not comparable with earlier results. The limited number of separate traders in the model reflects the problem of dimensionality. The model is run over 12 periods, six of which are reported here, as convergence is achieved within that time[3]. The adjustment coefficient ϵ is -0.3 for all countries for all time periods. The real discount rate is set at three per cent. The cost of stockholding increases with the discount rate. An autonomous growth in demand of three percent per year is assumed for all regions. This implies that storage will occur even if tariffs remain at zero, and thus relative reductions in storage are accommodated. Without growth in demand, there are periods in which tariffs are affected by the constraint that stocks cannot fall below zero. If the discount rate is much higher than the growth rate, stockholding is expensive compared with the world price changes, and few, if any, stocks are held. With zero growth and a five per cent discount rate, stocks would not be held. Once at or near the equilibrium, there is be no incentive to hold stocks, as the world price is stable.

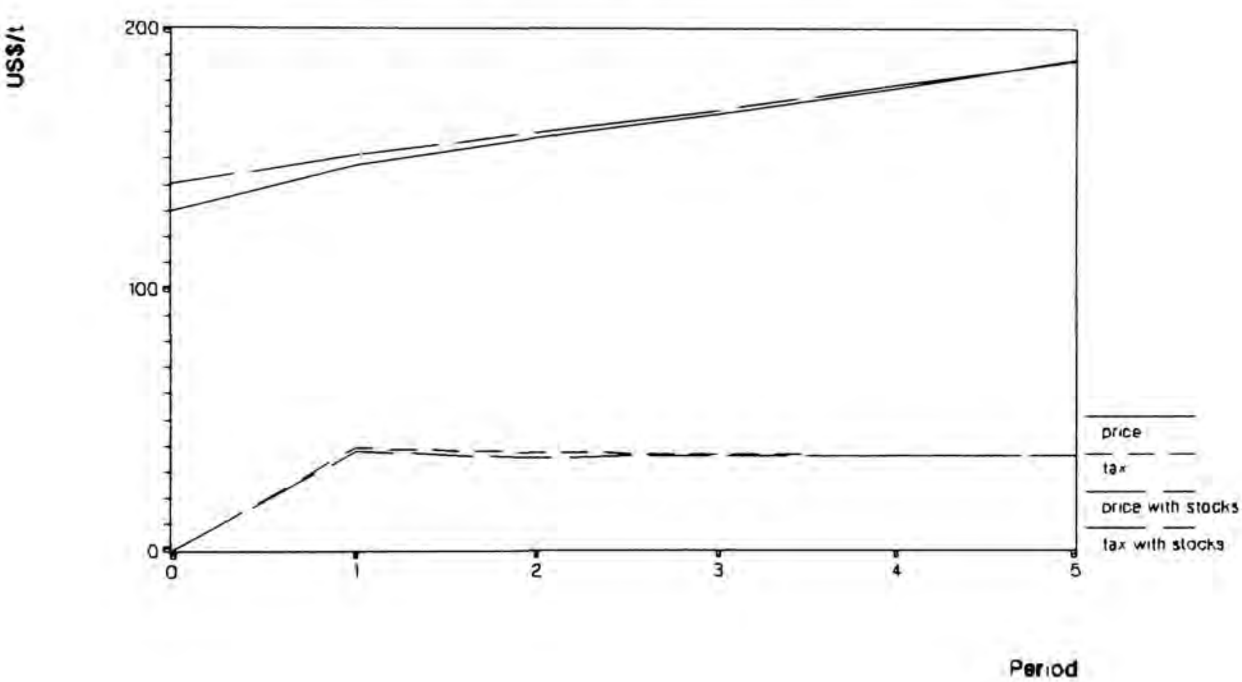
The reference period data are reproduced here, in Table 8.1. All prices are in US$ terms. The world price is taken as $128/t, the US Gulf Hard Red Winter Wheat price.

[3]Note that if the model solves in 10 complete iterations, 30 separate QP solutions must be calculated. The complete Cournot-Nash solution takes about 70 minutes of cpu time on a Vax 8800.

8.4.2 Impact of stockholding on tariffs in the absence of retaliation

In this model, the levels of stocks and tariffs in any given country are simultaneously determined, as policymakers set tariffs with a knowledge of how stockholders will behave, just as they know how producers and consumers will behave. However, to assess the impact of storage, it is useful to compare optimal solutions with and without storage. Export taxes for the USA, assuming other regions maintain a free trade policy and hold no stocks, are shown graphically in Figure 8.2, and in detail in Table 8.2. World prices are also shown. Period zero is the free trade solution. Stocks in period zero refer to the carryover from period zero to period one.

Figure 8.2: USA Export Taxes and World Prices



As previously, the optimal policy for an exporter, such as the United States, is an export tax. Market power is exercised, in the absence of stockholding, by applying a tax which lowers the domestic price and raises the world price. (Note, however, that there is an upward trend in prices here because of the autonomous growth in demand.) If storage is available, it is optimal to hold some stocks to abate some of the price increase. Average national welfare increases by a small margin, dependent upon the growth in demand, the discount rate and the cost of storage.

Table 8.2: Impact of Stockholding on USA Export Taxes and World Prices

Period	Without Stockholding		With Stockholding		
	Price (US$/t)	Tax (US$/t)	Price (US$/t)	Tax (US$/t)	Stocks (mmt)
0	130	0	140	0	4.92
1	147	39.26	152	37.65	9.18
2	158	37.40	160	35.43	11.84
3	167	36.51	169	35.59	13.42
4	178	35.74	178	35.93	14.43
5	188	35.58	188	36.18	14.58

Welfare without stocks: $19976m, welfare with stocks: $19989m.

In this deterministic model optimal stock levels are much lower than observed in practice. There are two main reasons for this. The existence of stochastic shocks necessitates a certain amount of storage, although with trade, this amount could not be expected to be great. The second factor is public stockholding, which reflects policies aimed at supporting producer incomes, rather than pure price stabilisation. The USA holds stocks that might otherwise be held by other nations, thus inflating the observed levels of stocks compared with the competitive optimums.

Storage does not have a significant effect on the level of optimal tariffs. Taxes are not noticeably different. The demand for grain by stockholders raises the price, regardless of taxes. This can be seen in period zero, where the tax is zero. Thus, prices are higher in the initial periods, in which stocks are built up, but are similar to prices without storage after three or four periods. One of the major reasons producers are in favour of buffer stock stabilisation schemes is that prices rise in the initial years of establishment of the scheme. The resulting benefits often outweigh the gains obtained from price stabilisation per se. Wright and Williams (1984) maintain that this is an important and neglected feature of models of price stabilisation.

8.3.3 The use of stockholding in countervailing market power

In the previous subsection it was noted that, for an individual country, storage does not appear to have much effect on the main instrument of market power, the export tax. What

8.4.3 The use of stockholding in countervailing market power

In the previous subsection it was noted that, for an individual country, storage does not appear to have much effect on the main instrument of market power, the export tax. What if other countries or regions can also impose taxes or hold stocks? How will this effect the optimal policies of any one country? This is determined by calculating the Cournot-Nash solution. The Cournot-Nash taxes for the USA and world prices are shown in Table 8.3. The solutions with and without storage can be compared.

When other countries also exercise market power, the USA taxes are fairly similar to the previous results. The effects of retaliation on taxes depends on whether market power is held predominantly by rival exporters (resulting in escalating taxes) or by importers (leading to a reduction in trade barriers). When the EC and Japan retaliate, prices rise from a free trade value of \$130 to \$171 instead of to \$188 as in the no-retaliation case.

A more significant change is in stockholding. In the previous solution, the USA held stocks of around 14 mmt, amounting to about 40 per cent of its exports. In the game-theoretic solution, with the EC and Japan holding stocks of 1.51 and 0.45 mmt, USA stocks are 1.14 mmt. That is, global stocks are significantly reduced. The taxes of the EC and Japan have smoothed prices to such an extent that it is no longer profitable for private stockholders to carryover so much in either the USA or in other countries.

The global effects are best seen in Table 8.4, where average tariff, stock and welfare levels are shown. The averages for the trade flow and the tariff exclude period zero, the free trade solution. The EC and Japan benefit by retaliating against the USA. These benefits derive mainly, but not entirely, from the trade barriers, rather than the availability of storage. When all interdependencies are taken into account, the option to store does not appear to have a great influence on trade barriers. The average world price is marginally lower, reflecting the influence of the lower EC export tax. Total trade is higher, and the USA has increased its market share. Japan has lowered its tariff, and increased its imports. As a consuming nation, it has benefited most from the storage that occurs in the rest of the world.

8.4.4 Storage costs and location

The location of storage across regions is primarily dependent upon relative costs of storage. For the results presented in Table 8.4, costs are assumed the same in each country and there are no transport costs. Thus storage in each region depends upon that region's ability to influence world prices, that is, its market power. The availability of storage in the EC and Japan has had little effect on world prices compared with a situation in which the world's stocks are held in the USA.

The welfare gains are sensitive to storage costs. In a separate analysis, the storage cost for the EC was raised from $5 to $7 per tonne. USA stocks averaged 1.45, up from 1.14 mmt. EC stocks fell to .55 from 1.51 mmt, and Japanese stocks fell from .45 to .37 mmt. Average global stocks have fallen from 3.1 to 2.37 mmt. The world price averaged $156, up from $151. National welfare in the USA rose slightly to $19438m, and fell in the EC and Japan to $22784m and $1301m respectively. This illustrates that storage costs in one country clearly influence welfare in others, through the effect on world price. The stockholding function is only partially transferred to a low cost country, the USA in this instance, because this country has the market power to extract greater benefits from stockholding than Japan. Where there are many consuming countries, the benefits of a reduction in world price from stockholding are dissipated.

8.4.5 A recapitulation

The major results from the empirical analysis are as follows. First, optimal storage levels are very low, much lower than is observed in a stochastic world where public as well as private stocks are held. Second, storage doesn't have a great effect on optimal tax levels. Third, when other countries can set tariffs and store, optimal USA taxes and world prices are relatively unchanged, but the optimal amount of storage declines significantly.

8.5 Implications

Stockholding can be used in countervailing market power, but its use is limited and outweighed by tariffs and taxes. The ability of a particular trader to use storage strategically depends on its own market power. Small countries with limited ability to influence the world price will store little or nothing, as the benefits of storage (a public good) cannot be captured.

This conclusion does not imply that stockholding cannot influence world prices and tariffs. Storage can affect these variables. However, the results suggest that the costs outweigh the benefits. Nonetheless, much public storage is held in situations in which the apparent benefits are negative, as government do not have the same financial incentives as the private storage sector.

What are the implications for public storage? Under the competitive storage assumptions employed here, there is no role for public stockholding, or, for example, imposition of a subsidy or tax on private stockholders. Public storage would exactly offset private storage, and would only be useful if private storage was constrained by limited capacity.

In this analysis storage is based on welfare optimisation, rather than on some trigger mechanism, as is common in many stockholding models. With positive storage costs or discounting, it is not desirable to stabilise prices perfectly. However, welfare levels are superior to those obtained from the implementation of storage band rules. This conclusion is, of course, dependent on the assumptions of risk neutrality and the policymakers' indifference between surplus going to the various groups.

Wright and Williams (1984) noted the importance of the degree of curvature of the demand curve as a determinant of the distribution of the gains from stabilisation. What can be inferred about nonlinear models from the analysis presented here? Unfortunately, little can be said about the Cournot-Nash solution, because nonlinearities may lead to the possibility of multiple solutions. In the no-retaliation case, the single controller problem, the need for stocks to reduce prices after a production shortfall is reduced as the curvature is increased. This implies that the linear model overestimates the stocks held and the welfare gains from stockholding.

Where international commodity markets are characterised by the use of market power and lags in production or policy responses, dynamic games provide a useful means of analysis. In this chapter a dynamic game model incorporating competitive storage has been developed. Stock levels and trade taxes are determined simultaneously. The results suggest that this is a significant step towards development of stochastic, strategic trade models.

Table 8.3: Impact of Stockholding on USA Cournot-Nash Taxes and World Prices

Period	Without Stockholding		With Stockholding		
	Price (US$/t)	Tax (US$/t)	Price (US$/t)	Tax (US$/t)	Stocks (mmt)
0	130	0.00	129	0.00	1.61
1	143	41.44	140	41.46	2.60
2	152	39.48	149	39.95	1.61
3	158	39.06	156	38.84	0.63
4	164	37.56	163	37.29	0.20
5	171	37.06	170	35.92	0.18

Welfare without stocks: $19583m, welfare with stocks: $19426m.

Table 8.4: Impact of Stockholding on Cournot-Nash Equilibrium

Solution with stockholding in parentheses

Region	Trade (mmt)	Tariff (US$/t)	Stocks (mmt)	Welfare (US$m)
United States	-27.44	-38.92	0.00	19583
	(-29.87)	(-38.73)	(1.14)	(19426)
EC	-9.77	-3.14	0.00	22793
	(-8.55)	(-2.34)	(1.51)	(22790)
Japan	4.86	7.08	0.00	1211
	(5.69)	(6.85)	(0.45)	(1306)

Average world price: $153 ($151).

Chapter 9

Conclusion

9.1 A Review

The major theme of this thesis is the strategic nature of agricultural trade. Strategic behaviour is a result of three features of agricultural trade: market power, government intervention and the public good problem.

Market power derives from the pattern of production, consumption and stockholding in the world. Like many food products, wheat is widely consumed, but production is more concentrated. A substantial proportion is traded, and much of the exportable surplus is provided by a few countries. Some countries have the potential to influence world prices. To exercise this potential market power, government intervention is necessary to combine individual producers or consumers into a unified group. Governments do this by using various policies which influence prices and quantities produced and consumed. Where market power exists, there is the potential for conflict between rival traders. Game-theoretic techniques provide a means of analysing conflicts of this type.

In practice, there is ample evidence of conflict. Trade disputes are quite common. Many conflicts seem to occur between the large trading nations, such as the USA, EC and Japan. Large countries often gain from trade disputes, whereas small traders benefit most from free trade.

Conflict involves strategy. Short-term losses may be compensated by long-term gains. Cooperation among traders provides trade gains, but for an individual country additional gains can be obtained by defection from a cooperative agreement, so long as other traders do not defect. In international agricultural trade, at least, the means of enforcing an agreement are limited, and noncooperative game-theoretic solutions are applicable. The noncooperative equilibria used empirically are Cournot-Nash, Stackelberg and conjectural variations.

The analysis described in this thesis extends previous work. Since the 1940s, there has been a moderate amount of trade-theoretic literature concerned with the optimal tariff. The problem of retaliation was more difficult to handle, because unless the nature of the response was clearly specified, the result was an indeterminate solution. Developments in other areas of economic analysis, especially industrial organisation, and the increasing realisation that trade is imperfectly competitive, led to applications of game theory. Simultaneously, a number of authors had treated the world wheat market as imperfectly competitive, and attempted to obtain solutions by assuming ad hoc cooperative behaviour. Others applied Cournot-Nash solutions, some less than satisfactorily. Encouraging developments in recent years include a conjectural variations model of the wheat market, and a dynamic Cournot-Nash solution applied to the world maize market. The applications in this thesis build on this work.

The major assumptions underlying the analysis are noncooperative behaviour, linear and deterministic supply and demand, and the use of a unit tariff as an instrument to optimise a national welfare function. The welfare function may be weighted according to policymakers' preferences to allocate resources to producers, consumers and taxpayers. One actor per country is assumed, and thus a game between interest groups and the government policymaker is subsumed. Cross-commodity effects are assumed to be insignificant.

In this thesis the model has been built up in stages, beginning with a static version with one domestic price. The results confirm that for countries with the ability to influence the world price, tariffs are optimal for an importer while export taxes are optimum for an exporter. A trade war leads to a Pareto inferior global outcome. However, some nations may be better off following a trade war than with free trade. If rivalry occurs on only one side of the market, the war tends to escalate after the first-round setting of tariffs by the country initiating the war. By contrast, if both exporters and importers set their optimum tax, the war is scaled down.

Many countries are not following a policy that maximises an unweighted welfare function. Export subsidies, for example, are not welfare maximising. To explain observed policies, and to predict a country's response to a policy change in another country, weights on the surplus attributed to various groups in society are estimated. The weights are consistent with the observed tariffs being the outcome of a Cournot-Nash process.

The analysis is extended to a two-price model. This allows estimates of the welfare weights on three, rather than two, separate groups: producers, consumers and taxpayers. These estimates assume that traders are at the Cournot-Nash equilibrium. Retaliation is taken into account.

The Cournot-Nash model is based on the condition that traders assume rivals will not respond, although they can be observed doing so. This response is taken into account in the conjectural variations solution. Various assumptions can be made about the expected retaliation. The approach used in this study involves estimating the aggregated response of all other countries. As each country faces a border price, it is not concerned with the individual responses of other countries, but with the resulting world price after all interactions are taken into account. The aggregated conjectural variations estimates are obtained from observed data using a revealed preference technique similar to that used to estimate the welfare weights.

The results indicate that expectations of retaliation can significantly influence the trade war outcome. Once conjectures were estimated, trade war solutions before and after a 20 per cent USA depreciation were compared with and without expectations of retaliation. With conjectures derived from the 1978-80 tariff levels, the conjectural variations trade war solution deviates more from free trade than the Cournot-Nash solution.

Dynamics are incorporated into the model by introducing a two-period supply lag.

Expected supply prices are based on a weighted average of prices received one and two periods in the past. A dynamic programming approach is used to solve the optimal control problem for each country, given the tariffs set by others. The dynamic Cournot-Nash solution is obtained by iteration, and in addition to confirming the results obtained from the static version of the model, enables the effects of varying the discount rate, time horizon and lag structure to be assessed. The response to a USA drought suggests that the optimal policy involves changing tariffs rather than quantities. Domestic prices are thus a stabilising influence. This contrasts with observed behaviour, possibly because stability is not taken into account in the welfare functions, which are additively separable. Hence, in the model a run of adverse years is no worse than the same number interspersed over the time horizon. In reality, this is not the case.

In another application, using the most recent data, a dynamic solution is obtained using static welfare weights. When setting a policy, it is important to take the weights of other countries into account, since these determine how rivals will respond. The analysis suggests that optimal policies are sensitive to quite small changes in the weights. The weighted trade war solution is further removed from free trade than the unitary weighted solution.

The weights provide a description of how other countries will react to a policy change. They should not be used in a normative sense as a justification for existing policies. In fact, the policies which maximise a weighted welfare function often impose substantial opportunity costs on society. This may come about through political failure; the result of national conflicts between various private interests and pressure groups. Broader social objectives, perhaps corrections for market failure, may not necessarily be reflected in the welfare weights.

When prices fluctuate over time, as in the dynamic model, competitive stockholders may be able to make profits by carrying stocks. If stockholding costs are not too high, gains from storage can be made even in the absence of stochastic shocks. When a trade war occurs, the price fluctuations due to the changes in tariff levels provide an opportunity for profits. This depends greatly on the costs of storage, including the discount rate, and the level of underlying growth in demand. With zero growth, and a positive rate of discount, stocks are held only in the initial periods of a trade war. The optimal tariff rates are affected only marginally. In a deterministic model, the introduction of private storage does not have a significant strategic role. The model is best viewed as a precursor to a dynamic, stochastic, strategic model.

Throughout the thesis, policymakers are assumed to maximise a welfare function. The one exception to this is the export subsidy war, where two countries set subsidies in an attempt to maintain a given market share. This objective is difficult to defend on economic grounds, although in strategic terms, it demonstrates a commitment to remaining a major exporter. A small change from equilibrium, due to a supply shift in non-subsidising countries, may result in a large fall in world price as the subsidising exporters attempt to regain a given share. Importing countries gain from this, while all exporters with a small domestic market face significant losses. This contrasts with an optimal tariff war, in which substantial tariffs do not affect the world price as greatly as in the export subsidy case.

The results obtained in the thesis can be related to the objectives stated in Chapter 1.

Is strategic behaviour a feature of agricultural trade?
While some agricultural markets may be perfectly competitive, it is apparent that market power exists in others, and that strategic behaviour is evident. This is to be expected not only from a theoretical perspective, but is also supported by empirical evidence. However, whereas export taxes or similar policies appear optimal, developed countries tend to employ trade policies which protect, rather than tax, producers.

Can strategic behaviour be described, explained and predicted?
Strategic behaviour can be described with game-theoretic structures. However, observed behaviour did not correspond closely to the trade war solutions. Welfare weights were used to explain observed behaviour. The weights were estimated in a static framework. No attempt has been made to explain or predict dynamic behaviour. Validation of the model (see Section 4) would contribute to this.

What are the effects of strategic behaviour? Are there winners from trade wars?
The effects of strategy on trade flows, prices and welfare can be assessed with static and dynamic games. Trade war solutions show the outcome if all countries impose their optimum policy. Some countries benefit from trade wars. Trade wars are not only winnable,

but are also self-limiting, and unlikely to result in the cessation of all trade. However, they will always result in a Pareto inferior global solution, although individual countries may be better off than with free trade.

What determines the optimal tariff?
Optimal tariff policy depends on market share and the relative demand and supply elasticities. The optimal tariff varies directly with the volume traded and the elasticities. Large traders, with substantial market power, have the greatest scope for sizeable tariffs. This has implications for cooperation.

What is the scope for cooperation?
The formal analysis in this thesis is based on a noncooperative framework. However, some observations about cooperation can readily be made. Because the optimal tariff increases with size, gains can be made through cooperation with other traders. The individual nations of the EC would not have the market power of the EC as a group. Cooperation invariably provides the potential for gains. However, the cost is the loss of sovereignty, as each country must act for the common benefit of the group. The difficulty in maintaining a coalition is in detecting and preventing free riding, as each country has an incentive to cheat on the agreement, so long as other members do not defect. The role of GATT and other institutions in providing assurance that free riding will be acceptably low is obvious. Unfortunately, the ability of GATT to perform this role, at least in agriculture, appears limited.

Is the use of export subsidies a suitable strategy?
Export subsidies appear to be used to show a commitment to stay in the market, to provide credibility to a threat. Hopefully, losses incurred in the short term will be compensated when rivals leave the market, or at least play a less significant role. What if one's rivals are subsidising? An export subsidy war leads very quickly to falling world prices and significant welfare losses in all exporting countries. Furthermore, any welfare objective, such as the maintenance of producer incomes, can be attained more efficiently by alternative policies.

9.2 Implications

Given the existence of strategic behaviour in the wheat market, the most appropriate policy for a small country is to attempt to modify the behaviour of large countries. One approach is to influence the weights which other countries attach to their welfare functions. This often involves providing consumers and taxpayers with information concerning the true costs of the country's policies. A second approach is to form a coalition with other small countries in an attempt to obtain market power. This may involve a system of sidepayments, perhaps by trading-off concessions on other, non-agricultural, products. However, in any coalition, defections must be minimised, and a system of measuring the degree of cooperation must be implemented. A third method of encouraging cooperation involves providing assurance that it will be maintained, for example by arguing for the efficiency of free trade and by demonstrating to other countries their commitment to it.

A large country has, of course, much more scope to behave strategically. As it can influence the world price, its behaviour can have an effect on others. Thus, its threats carry much greater force. Altering other countries' expectations of retaliation can significantly influence the final outcome. Credibility must be maintained if threats are to be taken seriously. However, there is a danger that if one's bluff is called, the resulting prisoners' dilemma outcome may be one which no country wants.

The results confirm that free trade is the globally superior policy, in the sense that all countries could be made better off than under any alternative set of trade policies. However, in the absence of sidepayments (compensation), some countries would be worse off. Compared with the policies currently in existence, importing countries would suffer from trade liberalisation. Nonetheless, many countries, particularly in the developed world, would benefit from free trade, and it is in the interest of these countries to encourage others to trade freely. However, large countries may well see it as in their interest to impose trade barriers, at least as long as other countries do not respond, and perhaps even if they do. The incentive which large countries have to renege on a free trade agreement is a point that other countries need to remember when conducting trade negotiations.

9.3 Contributions of this Study

The major contributions of this thesis include:

- the estimation of welfare weights from a Cournot-Nash equilibrium,
- the estimation of aggregated conjectural variations in a trade model,
- the derivation of a dynamic game-theoretic model with a two period lag,
- the simultaneous estimation of tariffs and stocks in a multiperiod quadratic programming model,
- the modelling of an export subsidy war, based on the maximisation of market shares, and
- the application of these various techniques to a twenty one sector world wheat market.

This thesis provides a framework for analysing strategic interaction. This is not new in itself, as many authors have examined optimal tariffs, and quite a number have treated the wheat market as an oligopoly. While game-theoretic models have been widely applied elsewhere, few have been applied to the wheat trade, or other international markets with many sectors, linear schedules and a welfare criterion.

A significant contribution of the thesis is to extend the work of Sarris and Freebairn (1983), who calculated a Cournot solution, but assumed all countries behaved as if they were small countries. This problem was rectified, and the welfare weights re-estimated.

The estimation of conjectural variations is similar to the approach of Paarlberg and Abbott (1986). Aggregated conjectures are estimated in a similar fashion to the method used to calculate the welfare weights, and applied to show the importance of expectations of retaliation.

The dynamic solution extends the work of Karp and McCalla (1983). A two-period dynamic difference game model is applied to a twenty one sector wheat model. Riccati equations are applied to solve the single controller problem. The contribution here involves specifying the welfare function in a fashion compatible with the solution technique[1]. While

[1] With the exception of the QP and matrix inversion and multiplication subroutines, all computer algorithms were written by the author in Fortran, and run on a VAX 8800 mainframe computer.

a two-period lag is not a complex control problem, it was necessary to derive the formulation from the supply and demand, price and market clearance equations. Trade war solutions with welfare weights were obtained.

Takayama and Judge (1971) derive QP models which solve for storage for given levels of import or export taxes, but in this thesis, the optimal storage and tariff levels are solved simultaneously. The solution is not unduly complex, but does not appear to have been reported in the literature. The QP model enabled an examination of the interaction between storage and trade taxes as strategic variables. This has hitherto received little attention.

Finally, the use of export subsidies to maintain market shares is often referred to in the daily press, yet there are few models of an export subsidy war. Those that have looked at this problem have assumed segmented markets or a heterogeneous product. Without these assumptions, the model presented here demonstrates that the rigid maintenance of market shares can be very expensive indeed, and can have significant effects on non-subsidising exporters.

The thesis thus makes a significant contribution in a number of areas. However, no thesis would be complete without a discussion of the scope for further developments and improvements.

9.4 Refinements and Extensions

In its present form, the model remains largely theoretical, with a degree of abstraction that does not permit detailed policy analysis. To make the model more suitable for this purpose, it would be necessary to undertake some of the steps outlined in this section.

9.4.1 Validation

As presented here, the model has not been validated. Validity could be assessed by the following experiment with the dynamic version of the model[2]. Begin the model from a representative period, in which the model is, hopefully, in equilibrium. 1980 might be such a period. Shock the model exogenously according to the changes in exchange rates, droughts, population and income, stocks, input costs and policy that have actually occurred during the 1980s. The changes, except for exchange rates, could be modelled as exogenous shifts of the demand and supply curves. This test would point out any deficiencies in the lag structure, and in the assumption of additive separability of the welfare functions. Additive separability refers to the intertemporal independence in the functions. Farmers, for example, are not unduly concerned about isolated years of adverse prices or incomes. Of greater concern is the occurrence of two or three bad years in a row. Governments face problems of a similar nature.

This validation procedure appears, at least superficially, easy to do. However, the model in its current state should be seen as theoretical and conceptual. The usefulness of the techniques is illustrated applying the model to the real world. It is not an empirical model which utilises game-theoretic concepts to estimate the costs of a trade war. Thus, as it is now, it lacks the detail to be suitable for policy analysis. To become so, it would be necessary to extend the model in some of the ways suggested in the remainder of the chapter. It would be more appropriate to validate the model following these refinements, rather than in its present form.

9.4.2 Stochastic

The model developed here is deterministic. Stochastic elements could be introduced, although this would necessitate reducing the number of regions or time periods if computational costs are to be maintained at the current level. At present, the welfare function does not take stability or uncertainty into account. Risk neutrality is assumed. Utility functions, with risk preferences, could replace the welfare functions employed here. A

[2]I am grateful to Rod Tyers for these suggestions.

stochastic model could reflect these concerns. In such a model, it is sensible to include stockholding, ideally as a control variable. This is an important extension to a trade model. The results presented in the previous chapter suggest that stocks have a minor role to play in a deterministic model, but their role may be much more significant in a stochastic model.

9.4.3 Cooperative Solutions

Perhaps the most interesting extension would involve incorporating collusive behaviour into the model. This could be done in the first instance by a simple aggregation of countries into regions or blocs. Coalitions of importers or exporters could be analysed, with the possibility of side-payments to deter cheating on agreements. For example, the so-called 'Cairns' group could be treated as one player, or as individual countries maximising a joint welfare function. One approach is to assume that there is only one decision maker, setting 14 different tariff levels. This ignores a game between the coalition members, just as in the noncooperative solution, a game between producers and government is assumed to have been played. Nonetheless, such a solution would enable assessment of the potential benefits of cooperation with one or more traders.

9.4.4 Multicommodity

The advantages in including different commodities in the model are two-fold. First, the introduction of other commodities into the model would enable some of the cross-commodity effects to be captured. This would probably necessitate a reduction in the number of regions. The extension may be computationally tedious, as it requires a simultaneous solution, for each country, for more than one control. Second, retaliation can occur in different markets. The markets may even be in sectors other than agriculture. As a first step, the major agricultural products could be modelled together in a game-theoretic framework, with each country setting optimal tariffs for each product.

9.4.5 Alternative Objective Functions

Different objective functions to those used here could be specified. Instead of optimising national welfare or market share, policymakers may see it as desirable to optimise exports, producer revenue, producer surplus or other objectives. Possibly, macro variables could be included. Karp and McCalla (1983) suggested balance of payments effects may be of interest. The welfare of other countries may also figure as an argument in each country's welfare function. Such terms may be positive or negative, depending on whether the other trader was an ally or not. For example, the USA could well attach a positive weight to the EC's welfare, and a negative weight to the USSR's. Finally, at present the welfare functions do not account for income effects. This could be remedied, for the sake of thoroughness, if not for improved accuracy.

9.4.6 Sensitivity Analysis

Sensitivity analysis has been performed on the welfare weights, and on the lag structure and some elasticities. However, this analysis could be approached more formally, with the various parameters being varied together according to some experimental design. Sensitivity analysis would reveal which parameters are the most important to the model, and greater care could be given to their value. Sensitivity analysis would also indicate the robustness of the model, its stability when subject to change in some parameters.

9.4.7 Expectations

The dynamic model contains a backward-looking two-period lag. This could readily be increased, although at some computational cost. A three-period lag would be quite manageable. A greater challenge would be to introduce forward-looking expectations. This raises the problem of time-inconsistency, in which solutions are dynamically inconsistent because of the influence of rational expectations of future choices on current decisions. A knowledge of tomorrow may affect the decisions made today. The time-inconsistency problem is explained at some length by Hughes Hallett (1984), and an example is given by Starr and Ho (1969). Conventional recursive optimisation techniques, such as dynamic programming, may lead to suboptimal solutions if forward-looking expectations are used. Karp (1987b) notes that with some additional assumptions, the tariff game with forward looking expectations can be solved, and indeed, Oudiz and Sachs (1984) provide a dynamic programming solution which could suitably be modified. Karp chose not to use this approach, maintaining that '*... it is not clear that it would provide a better representation of reality than the simpler version in which supply depends on lagged price*' (p. 4).

9.4.8 Nonlinearity

Linear models are often criticised for being unrealistic, especially if the price changes are other than small. Nonlinear models are less tractable, and introduce the possibility of multiple equilibria, or perhaps the absence of any equilibrium at all. The methods used here in the dynamic analysis depend on linearities, but there are quite a number of nonlinear programming packages available. Schittkowski (1984) provides a review of alternative packages. The introduction of nonlinearities would constitute a worthwhile extension to the research reported in the thesis.

In summary, by synthesising game theory and trade policy, this thesis makes a significant contribution in providing a theoretical background and an analytic method which enables an analysis of noncooperative strategic behaviour in agricultural trade.

Appendix A

National Wheat Policies

In this appendix, the policies of the major wheat traders are examined in some detail.

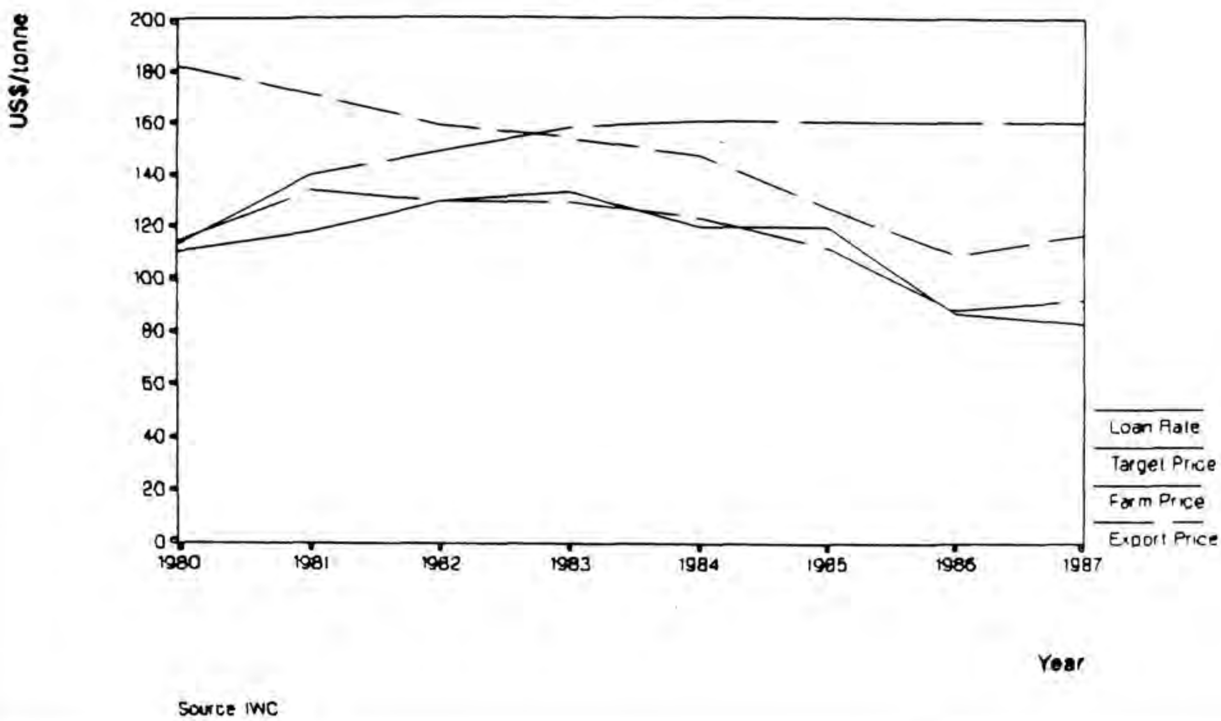
A.1 The United States of America

The main instruments of the American commodity program are the loan rate, the target price and deficiency payments scheme, the acreage reduction program and the export enhancement scheme. The main price variables are shown in Figure A.1.

The Food Security Act of 1985 sets out the main provisions relating to wheat (as well as other commodities). The Act was aimed at restoring some of the market share, lost due to the inflexibility of the previous Act, while maintaining support for producers. Producers are supported by the loan rate, the minimum price at which the Government will provide loans to farmers or purchase grain from farmers who choose not to redeem their loans. The loan rate sets a floor to the market, both domestically and internationally (exclusive of export subsidies). The loan rate determines the minimum border prices facing other countries.

The loan rate is set at between 75 per cent and 85 per cent of the average annual

Figure A.1: USA Loan Rate, and Target, Farm and Export Price



price received by producers over the preceding five years. Reductions must not exceed 5 percent. The Secretary of Agriculture has the discretion of reducing the rate even further if necessary. Repayment can occur at rates as low as 70 per cent of the original loan rate. These are known as marketing loans, and encourage farmers to repay loans at a lower rate and market the grain themselves. The government avoids the costs of transport and storage. The loan rate in 1988 was $79.73.

Target prices for producers receiving deficiency payments were $157.63/tonne in 1988, down some 5 per cent on the previous three years. Under the target option program, target prices are related to acreage reduction, whereby a higher price is received if the farmer idles more land than is specified under the Acreage Reduction Program. Farmers must comply with the ARP to obtain deficiency payments. In 1987, acreage reductions amounted to 27.5 per cent of the base area (the amount normally planted).

Parts of the Act relating to exports include the Export Enhancement Program (EEP), which is used to counter unfair foreign trade practices, such as export restitutions or export subsidies. Wheat export subsidies are undertaken through the EEP. (Additional funding is also provided under the Targeted Export Assistance Program.) This is probably the most contentious part of the Act, certainly as far as rival exporters are concerned. The subsidies are targeted at EC markets, with flow on effects occurring in other markets. Export subsidies will be discussed in greater detail later.

Other export provisions relate to direct export credits (blended credit), short-term credit (the GSM-102 programme), intermediate credits (the GSM-301 programme) and the Export Credit Revolving Fund. Food aid is dispensed under the Food for Peace (PL 480) programme.

The impact of the USA policies on the international wheat trade is substantial. Domestic policies have encouraged production, reduced world prices and led to a build-up in stocks. In contrast to other commodities, wheat support measures have been financed by the taxpayer, rather than the consumer. The costs of supporting producers has risen substantially in recent years. The cost of the US farm program was US$30 billion in 1986 (this includes all commodities), compared with US$3 billion in the early 1980s. Taxpayers provide subsidies amounting to $700 per non-farm family. The US farm programs represented 15 per cent of the Federal budget deficit in 1986 (ABARE p. 12). Consumer transfers amount to an additional $5 or $6 billion per year. For wheat, the producer subsidy equivalent was around 30 per cent in 1982-85, according to OECD estimates (reported in IAC p. E3). For 1986, a producer subsidy of 90 per cent was estimated. Using the Tyers model, the IAC calculated the impact on world wheat prices of the USA's policies to be -8.2 per cent (this was prior to the sustained use of export subsidies in 1987 and 1988).

A.2 Canada

The Canadian Wheat Board controls the marketing of wheat and some other grains. Deliveries are regulated by a quota system. Quotas vary as the grain is sold. Returns from the domestic and overseas markets are pooled.

The centerpiece of Canada's grain policy is the Western Grain Stabilization Act. This voluntary scheme is funded by growers and government and is aimed at maintaining cash flow when the current price is below the average of the previous five years. The government currently contributes 75 per cent of the cost of running the scheme. Payments totalled

$C580m in 1985-86.

Additional government support is provided in the form of subsidies on freight rates, crop insurance and credit, tax advantages and export assistance. In 1986, in response to low world prices, $C1 billion was provided under the Canadian Grains Program. Cash payments averaging $C5000 per farm were made in 1986 and 1987. The producer subsidy equivalent was around 27 per cent in the period 1982-85.

A.3 Australia

Like Canada, the marketing of Australian wheat is controlled by the Australian Wheat Board, which has sole acquisition rights (excluding stock feed sold under the permit system). Although domestic prices are generally higher than export prices, pooled returns tend to reflect the world price, as the domestic market is quite small. The objective the AWB is to maximise the return to growers, as required by the Commonwealth Wheat Marketing Act (1984) (IAC p. 30). Producer prices are underwritten by the Guaranteed Minimum Price. The GMP is 95 per cent of the estimated average of net pool returns for the current year and the lowest two of the three previous years. The government is required to make payments to the AWB when prices fall below the GMP. For the 1986-87 season, the government's contribution is expected to be about $220 m. However, the underwriting provisions are rarely required. This was the first payment since the scheme started in 1979. The government provides the financial backing for the Board's other marketing activities, such as futures trading, and the rolling over of credit to purchasers, such as Egypt, which have difficulty in meeting payments.

Apart from high prices for domestic consumers and price underwriting, other forms of assistance include an export inspection service, bounties on fertiliser, tractors, harvesters and other machinery (most of each bounty accrues to manufacturers), adjustment assistance, natural disaster relief and, most importantly, tax averaging provisions which are unavailable to non-farmers who may have fluctuating incomes. Negative assistance (costs) takes the form of tariffs and taxes on material and capital inputs. In comparison to other sectors and other exporters, the Australian wheat industry is lightly protected.

The producer subsidy equivalent was around 10 per cent in the early 1980s.

A.4 The European Community

The main instruments of EC policy are the intervention price, the target price, the threshold price, export restitutions and deficiency payments. The intervention price is the floor price below which farm prices cannot fall. It is related to the lowest market price in the EC (in Ormes, France) and was US$179.40 in 1986-87. The target price reflects the highest market price in the Community (Duisburg, Germany) US$256.11. The threshold price is the lowest price at which imports can enter the EC. Variable import levies are imposed to bring this price up to the target price less transport and handling costs. It was US$241.38 in 1986-87. Export restitutions reflect the difference between internal prices and the world market price. Deficiency payments are made to raise payments to growers to predetermined levels.

Two other policies of note are the green currency rates and the co-responsibility levy. The green rate convert agricultural prices expressed in the European Currency Units (ECU) into national currencies. These are changed from time to time. The co-responsibility levy is a tax on the output of cereals. It amounts to 3 per cent of the intervention price.

In the EC, subsidies and other support measures cost around US$23 billion in 1986-87. In addition to expenditure under the Common Agricultural Policy (which is funded by 1.4 per cent of the Value Added Tax) each member country supports its farmers to a similar degree. Consumers transfers have increased substantially, as domestic prices in the EC have not fallen with world prices. ABARE (1985) estimates that each nonfarm family is contributing around US$800 to support farmers (p. 4). According to the Tyers model, the effect of EC policies on world wheat prices was -7.7 per cent in 1986.

These costs are the direct costs of such programs. Indirect costs may be equally as large. These include efficiency losses, plus administrative costs and employment losses. In many cases, the distribution of income both within and beyond agriculture has been worsened. By contributing to world price instability, the EC has strained many historical trading and political ties. Relations between Australia and the USA and the EC are currently at a low ebb, due to the heavy subsidy programs entered into by the latter two countries. While estimates have been made of some of these indirect costs, it is difficult to apportion the costs of support for one individual commodity. Nonetheless, it is clear that wheat, along with dairy and sugar, is one of the industries that contributes substantially to the world agricultural crisis.

What is the European view of the agricultural crisis? With a legacy of food shortages during the depression of the 1930s and the Second World War, the Treaty of Rome (1957) gave agriculture a special place when the European Economic Community was formed. Agriculture was an inefficient and antiquated industry, and has been highly protected at least since the Treaty. As the CAP became increasingly operational, protection increased. As the bulk of production is consumed domestically, trade policy was, and remains, really about domestic industry assistance. Open-ended price supports are aimed at solving some loosely defined domestic objectives, while the impact on the world market is a less important consideration.

European intransigence regarding agricultural reform can be better appreciated by examining the trade policies of other countries in other industries. Textiles, clothing, footwear, steel, motor vehicles and electronics are just some of the industries in which substantial trade barriers exist. Australia and other agricultural exporters are not blameless in this respect. However, while some progress in reducing tariffs on manufactured goods has occurred after forty-odd years of the GATT, there has been only a disappointingly small amount of progress in reducing barriers to agricultural trade.

A.5 Argentina

The main feature of Argentinian policy until mid-1987 was an export tax. External creditors forced the removal of the 26.5 per cent tax, which was replaced by a land tax which may lead to grazing land being used for grain production. The Government, in severe economic difficulties, has taken a range of measures to increase exports, including more widespread increased used of new technology and agricultural inputs, the modernisation of the grain trading system, and the provision of concessional credit, at a rate of 3.5 per cent. The Argentine National Grain Board sets minimum producer prices and controls the flow of exports to ensure adequate domestic supplies.

A.6 USSR

Under the Food Program of the USSR, wheat production is planned to increase to self-sufficient levels in the near future (IWC p. 37). To achieve this, farmers receive premiums for production above set levels. In the early 1980s, domestic prices were estimated to be 10 per cent below border prices (IAC p. E3). If the target levels are met, the world grain trade will be substantially affected, as the USSR is currently the largest importer. The most notable characteristic of USSR policy is that imports appear to be related to requirements, rather than the world price.

A.7 China

Rapidly increasing production has characterised the Chinese wheat industry in recent years. Official targets for grain production have been set at the 1984 record level of 405 mmt. Transfer of land to some alternative activities is prohibited, and supplies of fertiliser and fuel have been increased. Areas under double cropping are to expanded (IWC p. 7). Production assistance is quite substantial. Producer prices exceeded border by 45 per cent in 1980-82.

A.8 Japan

Japan imports about 90 per cent of its wheat requirements. Producer prices are extremely high, at around Yen 10,000 per 60 kg ($1156 per tonne) in 1986-87. This represents the first decrease in 27 years. Consumer taxes amount to 185 per cent, compared with producer subsidies on wheat of 900 per cent. Estimates of the producer subsidy equivalents in the early 1980 range from 95 to 290 per cent in the (IAC p. E3). However, this has little effect on world prices, as production is so small. Of greater significance are consumer prices, which are well above world prices.

A.9 Brazil

The Brazilian government actively encourages increases in wheat production, through production subsidies and through the allocation of credit for the purchase of inputs. An objective is self-sufficiency, but with imports of 2.9 mmt in 1986-87, achieving this seems some way off. A consumption subsidy on wheat was removed in 1987.

A.10 Egypt

Egypt buys most of its wheat from Australia, and is Australia's third ranking customer, following the USSR and China. Egypt is heavily dependent on imports, producing less than one quarter of its consumption of about 9 mmt. At present, consumption is heavily subsidised. The government intends to reduce these subsidies, reducing consumption by 10 per cent. Prices paid to producers were increased by 40 per cent in 1986. These measures are aimed at reducing dependence on imports. Egypt has had difficulty paying for its purchases, and there has been some doubt concerning its ability to meet its loan repayments. This is of concern to the Australian Government, a major creditor.

A.11 India

India was a substantial wheat trader in the past, but has not imported foodgrains since 1985-86. Storage is limited to about 20 mmt. Exporting is difficult, because of the poor grain handling facilities. To reduce stocks, consumption is subsidised. In spite of the problems of disposal, production is expected to rise from 47 mmt in 1986 to 57 mmt in 1990.

Appendix B

Derivation of Supply and Demand Parameters

Given observed prices, quantities and elasticities, the demand and supply parameters can be calculated as follows

$$\beta_i = E_i^d * \bar{D}_i / \bar{P}_i^d, \tag{B.1}$$

$$\delta_i = E_i^s * \bar{S}_i / \bar{P}_i^s, \tag{B.2}$$

$$\alpha_i = \bar{D}_i + \beta_i \bar{P}_i^d, \tag{B.3}$$

$$\gamma_i = \bar{S}_i - \delta_i \bar{P}_i^s, \tag{B.4}$$

where E_i^d and E_i^s are the elasticities of demand and supply, $\bar{D}_i$ and $\bar{S}_i$ are observed levels of consumption and production, and $\bar{P}_i^d$ and $\bar{P}_i^s$ refer to observed prices paid by consumers and received by producers in country i.

Appendix C

Derivation of Surplus Measures

C.1 Consumer surplus

Given the demand relationship $D = \alpha - \beta P$, consumer surplus (CS in Figure C.1) is the area bounded by the demand curve and the price. The height of this area is given by $(P\{0\} - P\{D\})$. Hence,

$$CS = (\frac{1}{\beta}\alpha - \frac{1}{\beta}(\alpha - D))\frac{D}{2} \tag{C.1}$$

$$= \frac{D^2}{2\beta} \tag{C.2}$$

$$\tag{C.3}$$

Alternatively, in Figure C.1 CS is the area under the demand curve minus the expenditure. By integration,

$$CS = \int_0^D P\{D\}dD - P\{D\}D \tag{C.4}$$

$$= \frac{\alpha D}{\beta} - \frac{D^2}{2\beta} - \frac{1}{\beta}(\alpha - D)D \tag{C.5}$$

$$= \frac{D}{\beta}(\alpha - \frac{D}{2}) - \frac{D}{\beta}(\alpha - D) \tag{C.6}$$

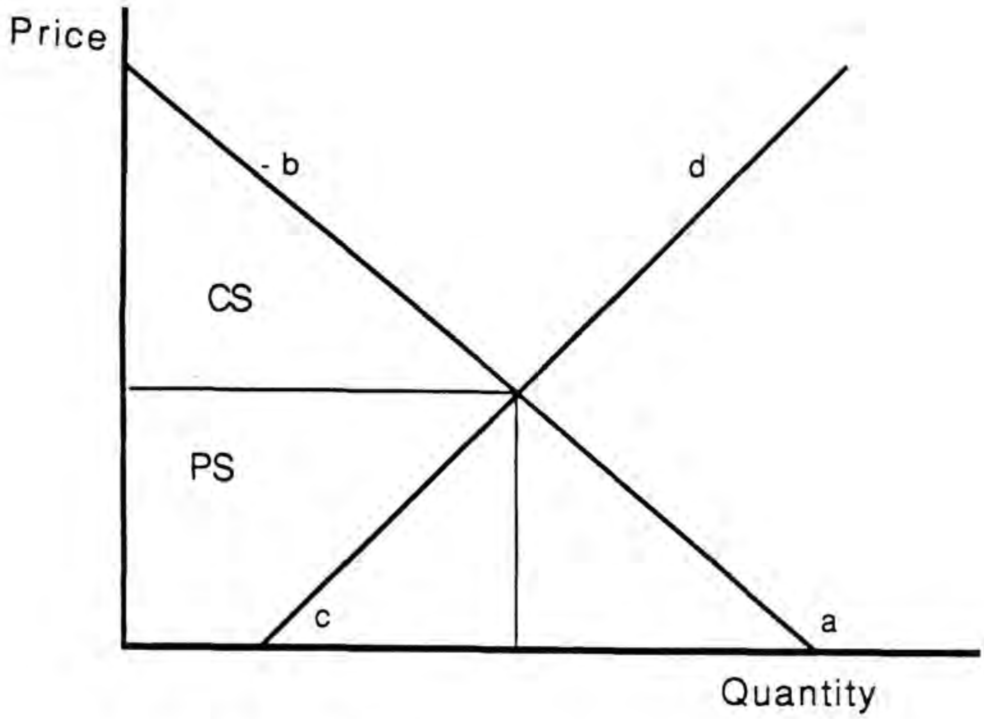


Figure C.1: Economic Surplus

$$= -\frac{D^2}{2\beta} + \frac{D^2}{\beta} \quad (C.7)$$

$$= \frac{D^2}{2\beta} \quad (C.8)$$

A common concern in empirical analysis is that consumer surplus measures may not correspond to welfare. Two willingness-to-pay measures may be used. Compensating variation is *'the amount of income which must be taken away from a consumer ... after a price and/or income change to restore the consumer's original welfare level'.* (Just, Hueth and Schmitz 1982, p. 85) Equivalent variation is *'the amount of income that must be given to a consumer ... in lieu of price and income changes to leave the consumer as well off as with the change.'* (Just et al. p. 85) To use these measures, demand curves need to be measured to compensate for changes in utility. These are known as 'Hicksian' demand curves. There are difficulties in measuring these curves empirically, and uncertainty as to whether compensated or equivalent variation measures should be used. Equivalent variation is the most commonly used method. An example can be found in Tyers (1984).

However, when the income elasticity of the good is zero, or the consumption of the product accounts for a small proportion of the consumer's total expenditure, than both measures are similar to ordinary surplus measures, using uncompensated, Marshallian curves. Willig (1976) notes that errors in estimating the demand curve swamp the errors involved in using economic surplus rather than compensated or equivalent variation as a measure of welfare. The assumption in this study is that wheat is such a small proportion of total expenditure that income effects can safely be ignored. This assumption may be debatable in relation to less developed countries, where purchases of wheat may comprise a significant proportion of total expenditure.

C.2 Producer surplus

Given the supply relationship $S = \gamma + \delta P$, producer surplus (PS) is the expenditure area minus the area under the supply curve between the intercept and the quantity supplied (assuming $\gamma \geq 0$). Noting that the height of the expenditure box is $(S - \gamma)/\delta$, then some simple algebraic manipulation gives

$$
\begin{aligned}
PS &= P.S - .5P(S - \gamma) &\text{(C.10)}\\
&= P.S - \frac{(S-\gamma)^2}{2\delta} &\text{(C.11)}\\
&= (\frac{S-\gamma}{\delta})S - \frac{(S-\gamma)^2}{2\delta} &\text{(C.12)}\\
&= \frac{S^2 - \gamma S}{\delta} - \frac{(S^2 - 2S\gamma + \gamma^2)}{2\delta} &\text{(C.13)}\\
&= \frac{2S^2 - 2\gamma S - S^2 + 2S\gamma - \gamma^2}{2\delta} &\text{(C.14)}\\
&= \frac{S^2 - \gamma^2}{2\delta}. &\text{(C.15)}
\end{aligned}
$$

Appendix D

Derivation of Optimal Tariff in Static One-Price Model

There are a number of ways of deriving the optimal tariff equation used in the static one-price model in Chapter 5. The approach outlined here is based on the requirement that for a welfare maximum, the producer and consumer deadweight losses are just equal to the tariff revenue attributed to a fall in the world price. The producer deadweight loss triangle has a slope $1/\delta$, height rx (where $r = \Sigma_{j \neq i}^{n}(\beta_j + \delta_j)/\Sigma_j^n(\beta_j + \delta_j)$ and x is the tariff) and, hence, base δrx. The area is thus $-(\delta rxrx)/2$. Likewise, the consumer deadweight loss triangle is $-(\beta rxrx)/2$.

Now consider the rectangle bordered by the quantities supplied and demanded, and the pre- and post-tariff world price. The height is $(1 - r)x$ and the length $(V - \delta rx - \beta rx)$ where V is the free trade volume of trade. The welfare function is

$$W = \frac{-r^2x^2}{2}(\beta + \delta) + (1 - r)x(V - \delta rx - \beta rx).$$

To solve for x^*, the welfare function is differentiated with respect to x and equated to zero.

$$\partial W/\partial x = -r^2x(\beta + \delta) + (1 - r)V - 2x(\delta r + \beta r)(1 - r) = 0$$

$$
\begin{aligned}
&= (\beta+\delta)(-r^2x - 2xr(1-r)) + (1+r)V = 0 \\
&= (\beta+\delta)rx(-r-2+2r) + (1+r)V = 0 \\
x &= \frac{-(1+r)V}{(r(-2+r)(\beta+\delta)} \\
x &= \frac{(1+r)V}{r(2-r)(\beta+\delta)}
\end{aligned}
$$

This is equation (6.12).

Appendix E

Derivation of H_{ij}.

From (6.12) and (6.17),

$$x_i^* = G_i V_i, \tag{E.1}$$

and from (6.6) and (6.16)

$$V_i = (\alpha_i - \gamma_i) - (\beta_i + \delta_i)P_i \tag{E.2}$$

where

$$P_i = \frac{\Sigma(\alpha_j - \gamma_j) - \Sigma_{j \neq i} x_j(\beta_j + \delta_j)}{\Sigma(\beta_j + \delta_j)} \tag{E.3}$$

P_i is the world price which would prevail given x_j for all $j \neq i$ and $x_i = 0$. It can be rewritten as

$$P_i = P - \frac{\Sigma_{j \neq i} x_j(\beta_j + \delta_j)}{\Sigma(\beta_j + \delta_j)} \tag{E.4}$$

where P is the free trade world price. Thus

$$\begin{aligned} V_i &= (\alpha_i - \gamma_i) - (\beta_i + \delta_i)[P - \frac{\Sigma_{j \neq i} x_j(\beta_j + \delta_j)}{\Sigma(\beta_j + \delta_j)}] && \text{(E.5)} \\ &= (\alpha_i - \gamma_i) - (\beta_i + \delta_i)P + \frac{(\beta_i + \delta_i)\Sigma_{j \neq i} x_j(\beta_j + \delta_j)}{\Sigma(\beta_j + \delta_j)} && \text{(E.6)} \\ x_i^* &= G_i[(\alpha_i - \gamma_i) - (\beta_i + \delta_i)P] + \frac{G_i(\beta_i + \delta_i)\Sigma_{j \neq i} x_j^*(\beta_j + \delta_j)}{\Sigma(\beta_j + \delta_j)} && \text{(E.7)} \\ &= k_i + \Sigma_{j \neq i} x_j^* h_{ij} && \text{(E.8)} \end{aligned}$$

In matrix notation,

$$x_i^* - \Sigma_{j\neq i} x_j^* h_j = k_i \tag{E.9}$$

$$[I - H]\, x^* = k \tag{E.10}$$

Hence,

$$\begin{aligned} H_{ij} &= \frac{-G_i(\beta_i + \delta_i)(\beta_j + \delta_j)}{\Sigma(\beta_j + \delta_j)} \quad for\ i \neq j \\ &= 1 \quad for\ i = j. \end{aligned} \tag{E.11}$$

which is equation (6.16).

Appendix F

Alternative Static Solution Algorithms

The simultaneous solution method of obtaining the Cournot-Nash equilibrium described in Chapter 5 depends upon the inversion of an (nxn) matrix. If n is very large, or if the path to equilibrium is of interest, an iterative approach may be more suitable. Equation (6.12) provides an estimate of each country's optimal tariff without retaliation. Once tariffs are determined in all countries, equation (6.6) shows how the tariffs can be incorporated into the world price equation. The new world price changes trade flows, which makes the existing tariff levels no longer optimal. New tariffs are calculated, with V_i in equation (6.14) being that level of trade that would occur if $x_i = 0$. The process iterates to a stable and unique equilibrium.

The simultaneous and iterative methods depend upon horizontal aggregation of excess supply and demand. A possible problem here is that because the supply and demand curves are not defined for negative quantities, there may be kinks in the aggregate excess supply or demand curves. This problem arises if the optimal D or S falls to zero in any region. If a kink occurs, it results in inaccurate estimates of welfare and hence optimum tariffs.

An alternative approach, which avoids the aggregation problem and allows for the incorporation of transport costs, is to use quadratic programming[1].

The programming problem involves finding a vector y that maximises a quadratic objective function subject to constraints

$$Max \ W_i = p'y + \frac{1}{2}y'Qy \tag{F.1}$$

$$s.t. \ Ay \leq b \tag{F.2}$$

$$y \geq 0. \tag{F.3}$$

where A is an (mxn) matrix, Q is an (nxn) positive semi-definite quadratic matrix, and b is a vector of constraints (in this case, the demand and supply intercept terms).

There are a variety of ways of specifying the objective function. The method used here includes consumer and producer surplus separately, and assumes the supply intercept exceeds zero, as is the case with the data used in this study.

The objective function is

$$U = \frac{1}{2}[\frac{D^2}{\beta} + \frac{S^2}{\delta} - \frac{\gamma^2}{\delta}] + x\ D - x\ S. \tag{F.4}$$

The A and Q matrices, and b and y vectors are as follows

[1]Yet another alternative is nonlinear complementarity programming. This is an efficient programming method, possibly superior to the iterative Quadratic Programming approach described here. However, except when transport costs are to be included or certain (unusual) aggregation problems arise, no programming method is likely to be superior to the simultaneous solution procedure used here.

$$A = \begin{bmatrix} 1 & & & & \beta_1 & \beta_1 & -\beta_1 \\ & 1 & & & -\delta_1 & -\delta_1 & \delta_1 \\ & & 1 & & \beta_2 & & \\ & & & 1 & -\delta_2 & & \\ \vdots & \vdots & \vdots & \vdots & \vdots & & \\ 1 & -1 & 1 & -1 & & & \end{bmatrix}_{(2n+1)x(2n+3)}$$

$$Q = \begin{bmatrix} 1/\beta_1 & & & & & 1 & -1 \\ & & 1/\delta_1 & & & -1 & 1 \\ \vdots & & \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & -1 & & & & & \\ -1 & 1 & & & & & \end{bmatrix}_{(2n+3)x(2n+3)}$$

These matrices are set to solve the optimum tariff for country 1. Clearly, the final two columns in the A matrix and the entire Q matrix are altered to solve for other traders.

$$b = [\alpha_1 \ \gamma_1 \ \alpha_2 \ \gamma_2 \ \cdots \ 0]_{(2n+1)}$$

$$x = [D_1 \ S_1 \ D_2 \ S_2 \ \cdots \ P \ x \ x^e]_{(2n+3)}$$

P refers to price, x to tariff or export subsidy, and x^e to export tax.

To estimate welfare weights, a weighted objective function is required

$$W_i = \frac{1}{2}[w_{ci}\frac{D^2}{\beta} + w_{pi}\frac{S^2}{\delta} - w_{pi}\frac{\gamma^2}{\delta}] + w_{gi}x_i(D_i - S_i) \tag{F.5}$$

where w_{ci}, w_{pi} and w_{gi} refer to the weight given to consumers, producers and taxpayers respectively.

The A matrix for a two-region model is as specified earlier, but the Q matrix requires modification, as is shown below. Note that to calculate optimum policies within quadratic programming, w_{ci} and w_{gi} need not be constrained to be equal. That constraint is imposed during estimation of the weights, in which quadratic programming plays no part.

With the addition of welfare weights, the Q matrix becomes

$$Q = \begin{bmatrix} w_{ci}/\beta_1 & & & & & w_{gi} & -w_{gi} \\ & w_{pi}/\delta_1 & & & & -w_{gi} & w_{gi} \\ \vdots & \vdots & \vdots & \vdots & & \vdots & \vdots \\ w_{gi} & -w_{gi} & & & & & \\ -w_{gi} & w_{gi} & & & & & \end{bmatrix}_{(2n+3)x(2n+3)}$$

An iterative process can be applied to the QP model. In this case, the constraints, in the b vector (the intercept terms), are altered each iteration as follows

$$\alpha_i' = \alpha_i - \beta_i x_i \qquad (F.6)$$

$$\gamma_i' = \gamma_i + \delta_i x_i \qquad (F.7)$$

where α_i' and γ_i' are the updated values, and α_i and γ_i are the starting (free trade) values. They are not updated. Iterations continue until convergence is obtained.

The QP technique cannot provide a simultaneous solution, but it does avoid the possibility of aggregation errors described earlier. It also allows for the inclusion of transport costs and other impediments to trade. In this study, transport costs are not included, and aggregation errors were not found to be a problem. The QP routine was used to confirm results obtained by the other procedures.

Appendix G

Open Loop Optimal Control Solution

An alternative solution technique to the Riccati equation method is described by Kydland (1975). It involves subsuming every period's welfare function into one large function, and rewriting all the state equations in terms of the initial state y_0. The welfare function becomes

$$W = r'y + \frac{1}{2}y'Ky, \tag{G.1}$$

where

$$r' = [r_1, \psi r_2, ..., \psi^{T-1} r_T] \tag{G.2}$$

$$y' = [y_1, y_2, ..., y_T] \tag{G.3}$$

$$K = \begin{bmatrix} K_1 & & & \\ & \psi K_2 & & \\ & & \ddots & \\ & & & \psi^{T-1} K_T \end{bmatrix}$$

The state equation is

$$y = Ay_0 + Bx + c \tag{G.4}$$

where

$$A' = [A, A^2, ..., A^T], \tag{G.5}$$

$$B = \begin{bmatrix} B & & & \\ AB & B & & \\ A^2B & AB & B & \\ \vdots & \ddots & \ddots & \\ A^{T-1}B & A^{T-2}B & \cdots & B \end{bmatrix}$$

$$x' = [x_1, x_2, ..., x_T] \tag{G.6}$$

and

$$C = [c, Ac + c, A^2c + Ac + c, ..., \Sigma_{i=0}^{T-1} A^i c] \tag{G.7}$$

As these equations are now in the same form as equations (8.22) and (8.23), they can be solved in the usual way by differentiation with respect to x, equating to zero, and solving x to obtain maximum discounted welfare for the T periods.

The results obtained using this procedure confirmed those obtained using the Riccati equations. It is less suitable than the Riccati approach for large models, however, as it involves the inversion of increasingly large matrices as the time period increases.

Appendix H

Simplified K_i matrix

The K_i matrix with all welfare weights equal to unity and $\epsilon_i = 0$ is as follows. This is comparable to equation (8.17).

$$K_i = \begin{bmatrix} \beta_i & 0 & \delta_i & \delta_i & 0 \\ 0 & -\beta_i & 0 & 0 & 0 \\ \delta_i & 0 & -\delta_i & -\delta_i & 0 \\ \delta_i & 0 & -\delta_i & -\delta_i & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}_{(5x5)}$$

Appendix I

Publications by the Author

The following pages contain a comment published in the *American Journal of Agricultural Economics* and referenced as Vanzetti and Kennedy (1988b). An extended version of this material is incorporated into Chapter 5.

A version of Vanzetti and Kennedy (1988c) has been submitted to *The Review of Marketing and Agricultural Economics* at the invitation of the editor, and a version of Vanzetti (1988) is being considered for publication at the *Economic Record.* Material from these articles is contained in Chapters 6 and 7.

Unpublished work by the author is referenced in the bibliography.

Endogenous Price Policies and International Wheat Prices: Comment

David Vanzetti and John Kennedy

In a 1983 article in this *Journal* Sarris and Freebairn claim to model international wheat prices as Cournot equilibrium prices resulting from the interaction of national excess demand functions. National pricing policies are determined so as to maximize a domestic welfare function, specified as a weighted sum of producer and consumer surplus, government revenue, and a price variability measure. The function is maximized subject to the pricing policies of all other countries. In the Sarris and Freebairn model, each country assumes that any pricing policy which it implements, such as the imposition of a tariff, will not affect the world price. We contend that this assumption is not consistent with the usual determination of a Cournot equilibrium. In the Cournot oligopoly model, each firm takes account of the price implications of the output it sets. Therefore, we reformulate Sarris and Freebairn's model to account for the impact of policies on the world price and recalculate the implicit welfare weights for wheat-trading countries.

In the traditional Cournot oligopoly model, each firm takes account of production levels set by it and other firms, although each (naively) expects no response from its rivals. The Cournot-Nash equilibrium is a point at which no trader (acting unilaterally) can do better than playing its optimal strategy, given that all other traders are playing their optimal strategies. Interaction between the traders leads to convergence to an equilibrium from which none would want to move. In contrast to the traditional model, Sarris and Freebairn derive their solution on the simplifying assumption that "every trading country takes [the world price] as given. . . . [This] implies that each country is concerned with domestic objectives and is not concerned with other countries' reactions to its policies. In other words, we posit a Cournot oligopoly problem" (p. 215). In fact, Sarris and Freebairn posit zero conjectural variations (i.e., each trader conjectures that its rivals will not vary their policies) as in a Cournot model but assume no effect on world prices. This latter assumption is not consistent with a Cournot model.

In a Cournot-Nash model, traders assume that rivals do not respond to their policies, although these (zero) conjectures are subsequently found to be incorrect. Although unanticipated, retaliation does occur, and by imposing the assumption of a given world price, and that market power remains unused, Sarris and Freebairn are led to conclude that with equal weights on all components of the welfare function, "the optimal policy for the country is a free-trade one" (p. 216). This conclusion is consistent with the simplifying small country assumption. However, it is unlikely that countries with market power will ignore it in setting tariffs. After dropping this assumption, our calculations (presented in table 1) show that the optimal policies are nonzero even if weights are equal.

The method used here for obtaining the Cournot-Nash solution involves calculating the first-order conditions to maximize a weighted welfare function for each country. The reaction functions, showing how each country reacts to tariffs imposed by others, can then be derived.[1] The functions can be solved simultaneously to obtain the Cournot-Nash solution.[2]

Consider a homogenous product traded between n countries with linear demand and supply curves:

$$QD_i = \alpha_i - \beta_i P_i^d \tag{1}$$

$$QS_i = \gamma_i + \delta_i P_i^s \tag{2}$$

where QD_i and QS_i denote quantities demanded and supplied in country i; P_i^d and P_i^s denote the current price paid by consumers and received by producers, respectively; and α_i, β_i, γ_i and δ refer to the usual intercept and slope parameters, which are all nonnegative. To keep the algebra to a minimum, there are no additive disturbance terms in (1) and (2), unlike the demand and supply equations specified by Sarris and Freebairn. It is argued later that this does not lead to a bias in the estimates of expected tariffs or welfare weights. Assuming no change in stocks, and therefore market clearance:

$$\Sigma_i^n (QD_i - QS_i) = 0. \tag{3}$$

The market clearing free trade price is

$$P^f = \frac{\Sigma_i^n(\alpha_i - \gamma_i)}{\Sigma_i^n(\beta_i + \delta_i)}. \tag{4}$$

The authors are a postgraduate student and a senior lecturer, respectively, at La Trobe University, Australia.

[1] The term "tariff" refers here to any policy leading to a difference between the world price and producer or consumer prices. Negative values represent export taxes.

[2] Alternatively, once equations for the optimal policy (assuming no retaliation) have been derived for each country acting independently, a solution can be found by iteration. An example of such a procedure is described by Vanzetti and Kennedy.

Table 1. Cournot-Nash Equilibrium and Observed Tariffs, and Implicit Welfare Weights

	t^d	t^s	$\bar{t}^d$	$\bar{t}^s$	*Wc*	*Wp*	*Wg*
	Equilibrium[a]		Observed			Estimated[b]	
Region	\$/t	\$/t	\$/t	\$/t			
United States	−70.01 (0.00)[c]	70.01 (0.00)	0.00	0.00	0.917 (1.000)	1.091 (1.000)	0.992 (1.000)
Canada	−31.37 (0.00)	31.37 (0.00)	0.00	0.00	0.976 (1.000)	1.029 (1.000)	0.995 (1.000)
Australia	−30.33 (0.00)	30.33 (0.00)	17.00	0.00	0.975 (0.993)	1.022 (1.003)	1.003 (1.003)
Argentina	−8.81 (0.00)	8.81 (0.00)	−35.00	35.00	1.016 (1.021)	0.978 (0.972)	1.005 (1.007)
EC	−3.03 (0.00)	3.03 (0.00)	63.00	−63.00	0.915 (0.930)	1.102 (1.084)	0.983 (0.986)
South Africa	−0.64 (0.00)	0.64 (0.00)	17.00	0.00	0.995 (0.995)	1.003 (1.002)	1.002 (0.989)
Other Western Europe	2.03 (0.00)	−2.03 (0.00)	63.00	−63.00	0.930 (0.930)	1.084 (1.084)	0.986 (0.986)
Japan	12.12 (0.00)	−12.12 (0.00)	42.00	585.00	0.953 (0.944)	1.061 (1.067)	0.985 (0.989)
Brazil	8.21 (0.00)	−8.21 (0.00)	−8.00	−53.00	0.998 (0.992)	1.016 (1.023)	0.985 (0.986)
Central America & other South America	12.22 (0.00)	−12.22 (0.00)	12.00	−12.00	1.001 (0.988)	0.999 (1.011)	1.000 (1.000)
Egypt	8.88 (0.00)	−8.88 (0.00)	−38.00	38.00	1.062 (1.048)	0.945 (0.957)	0.993 (0.995)
Other North Africa & Middle East	21.06 (0.00)	−21.06 (0.00)	42.00	−42.00	0.990 (0.980)	1.007 (1.014)	1.003 (1.006)
Other Africa	5.58 (0.00)	−5.58 (0.00)	17.00	−17.00	0.986 (0.979)	1.012 (1.018)	1.002 (1.003)
India	−0.48 (0.00)	0.48 (0.00)	0.00	0.00	1.005 (1.000)	0.996 (1.000)	0.999 (1.000)
Other South Asia	1.93 (0.00)	−1.93 (0.00)	−34.00	34.00	1.055 (1.045)	0.956 (0.964)	0.989 (0.991)
South East Asia	2.63 (0.00)	−2.63 (0.00)	−8.00	8.00	1.007 (1.005)	0.993 (0.995)	1.000 (1.000)

[a] These are equilibrium values assuming unitary weights.
[b] Weights if observed tariffs were at their Cournot-Nash equilibrium levels.
[c] Results from Sarris and Freebairn are shown in parentheses.

The introduction of differential prices for domestic producers (P^s) and consumers (P^d) separates domestic and international prices. The market clearing tariff-ridden world price is now

$$P^w = \frac{\Sigma_i^n(\alpha_i - \gamma_i) - \Sigma_i^n(\beta_i t_i^d - \delta_i t_i^s)}{\Sigma_i^n(\beta_i + \delta_i)}, \quad (5)$$

where

$$t_i^d = P_i^d - P^w \quad (6)$$

$$t_i^s = P^w - P_i^s. \quad (7)$$

With linear schedules, and the inclusion of the welfare weights, the total welfare function to be maximized for country i is

$$U_i = W_{ci}CS_i + W_{pi}PS_i + W_{gi}TR_i \quad (8)$$

with

$$CS_i = \frac{QD_i^2}{2\beta_i} \quad (9)$$

$$PS_i = \frac{QS_i^2 - \gamma_i^2}{2\delta_i} \quad (10)$$

$$TR_i = t_i^d QD_i + t_i^s QS_i. \quad (11)$$

CS_i, PS_i, and TR_i refer to consumer surplus, producer surplus, and tariff revenue, respectively, and *W*s are the appropriate weights.[3] The weights reflect the policy makers' preferences for the distribu-

[3] Equation (10) for PS_i assumes γ exceeds zero, as is the case for all data used here. If γ is negative, $PS_i = QS_i^2/2\delta_i$. The difference, $-\gamma_i^2/2\delta_i$, is a constant which drops out upon differentiation.

tion of surplus to consumers, producers and taxpayers. QD_i and QS_i now depend on t_j^d and t_j^s for all j.

Setting the partial derivatives of U_i with respect to t_i^d and t_i^s equal to zero, for an interior solution, gives

$$(12)\quad \partial U_i/\partial t_i^d = \frac{W_{ci}X_{3i}}{\beta_i}\left[\alpha_i - \beta_i P^f + t_i^d X_{3i} + \beta_i \frac{\Sigma_{j\neq i}\beta_j t_j^d}{BD} + t_i^s X_{1i} - \beta_i \frac{\Sigma_{j\neq i}\delta_j t_j^s}{BD}\right]$$
$$+ \frac{W_{pi}X_{1i}}{\delta_i}\left[\gamma_i + \delta_i P^f + t_i^d X_{1i} - \delta_i \frac{\Sigma_{j\neq i}\beta_j t_j^d}{BD} + t_i^s X_{2i} + \delta_i \frac{\Sigma_{j\neq i}\delta_j t_j^s}{BD}\right]$$
$$+ W_{gi}\left[\alpha_i - \beta_i P^f + 2t_i^d X_{3i} + \beta_i \frac{\Sigma_{j\neq i}\beta_j t_j^d}{BD} + 2t_i^s X_{1i} - \beta_i \frac{\Sigma_{j\neq i}\delta_j t_j^s}{BD}\right]$$
$$= 0;$$

$$(13)\quad \partial U_i/\partial t_i^s = \frac{W_{ci}X_{1i}}{\beta_i}\left[\alpha_i - \beta_i P^f + t_i^d X_{3i} + \beta_i \frac{\Sigma_{j\neq i}\beta_j t_j^d}{BD} + t_i^s X_{1i} - \beta_i \frac{\Sigma_{j\neq i}\delta_j t_j^s}{BD}\right]$$
$$+ \frac{W_{pi}X_{2i}}{\delta_i}\left[\gamma_i + \delta_i P^f + t_i^d X_{1i} - \delta_i \frac{\Sigma_{j\neq i}\beta_j t_j^d}{BD} + t_i^s X_{2i} + \delta_i \frac{\Sigma_{j\neq i}\delta_j t_j^s}{BD}\right]$$
$$+ W_{gi}\left[\gamma_i + \delta_i P^f + 2t_i^d X_{1i} - \delta_i \frac{\Sigma_{j\neq i}\beta_j t_j^d}{BD} + 2t_i^s X_{2i} + \delta_i \frac{\Sigma_{j\neq i}\delta_j t_j^s}{BD}\right]$$
$$= 0,$$

where $BD = \Sigma_j^n(\beta_j + \delta_j)$, and

$$X_{1i} \equiv \frac{-\beta_i\delta_i}{BD} = \frac{\partial QD_i}{\partial t_i^s} = \frac{\partial QS_i}{\delta t_i^d}$$
$$X_{2i} \equiv \frac{\delta_i^2}{BD} - \delta_i = \frac{\partial QS_i}{\partial t_i^s}$$
$$X_{3i} \equiv \frac{\beta_i^2}{BD} - \beta_i = \frac{\partial QD_i}{\partial t_i^d}.$$

These equations hold simultaneously for n countries. After rearrangement, they can be expressed in matrix notation as

$$(14)\quad At = g,$$

where

$$A = \begin{bmatrix} a_1 & b_1 & \beta_2 z_1 - \delta_2 z_1 & \ldots & \beta_n z_1 - \delta_n z_1 \\ b_1 & c_1 & \beta_2 y_1 - \delta_2 y_1 & \ldots & \beta_n y_1 - \delta_n y_1 \\ \beta_1 z_2 - \delta_1 z_2 & a_2 & b_2 & \ldots & \beta_n z_2 - \delta_n z_2 \\ \beta_1 y_2 - \delta_1 y_2 & b_2 & c_2 & \ldots & \beta_n y_2 - \delta_n y_2 \\ \vdots & & & & \vdots \\ \beta_1 z_n - \delta_1 z_n & \beta_2 z_n - \delta_2 z_n & \ldots & a_n & b_n \\ \beta_1 y_n - \delta_1 y_n & \beta_2 y_n - \delta_2 y_n & \ldots & b_n & c_n \end{bmatrix}$$

$$t' = [t_1^d t_1^s t_2^d t_2^s \ldots t_n^d t_n^s]$$
$$g' = [g_1^d g_1^s g_2^d g_2^s \ldots g_n^d g_n^s].$$

In matrix A

$$(15)\quad a_i = \frac{W_{ci}}{\beta_i}X_{3i}^2 + \frac{W_{pi}}{\delta_i}X_{1i}^2 + 2W_{gi}X_{3i}$$

$$(16)\quad b_i = \frac{W_{ci}}{\beta_i}X_{1i}X_{3i} + \frac{W_{pi}}{\delta_i}X_{2i}X_{1i} + 2W_{gi}X_{1i}$$

$$(17)\quad c_i = \frac{W_{ci}}{\beta_i}X_{1i}^2 + \frac{W_{pi}}{\delta_i}X_{2i}^2 + 2W_{gi}X_{2i}$$

$$(18)\quad z_i = \frac{W_{ci}X_{3i} - W_{pi}X_{1i} + W_{gi}\beta_i}{\Sigma_j^n(\beta_j + \delta_j)}$$

$$(19)\quad y_i = \frac{W_{ci}X_{1i} - W_{pi}X_{2i} - W_{gi}\delta_i}{\Sigma_j^n(\beta_j + \delta_j)}.$$

In vector g'

$$(20)\quad g_i^d = \frac{-W_{ci}X_{3i}\alpha_i}{\beta_i} - \frac{W_{pi}X_{1i}\gamma_i}{\delta_i} - W_{gi}\alpha_i + P^f(W_{ci}X_{3i} - W_{pi}X_{1i} + W_{gi}\beta_i)$$

$$(21)\quad g_i^s = \frac{-W_{ci}X_{1i}\alpha_i}{\beta_i} - \frac{W_{pi}X_{2i}\gamma_i}{\delta_i} - W_{gi}\gamma_i + P^f(W_{ci}X_{1i} - W_{pi}X_{2i} + W_{gi}\delta_i).$$

Equation (14) can be solved by matrix inversion to provide the Cournot-Nash equilibrium tariffs:

$$(22)\quad t = A^{-1}g.$$

If the intercept terms of the demand and supply equations [α_i and γ_i in (1) and (2)] were stochastic, equation (22) would still solve for expected tariffs if the intercept terms on the right-hand side were set at their expected values. This follows because the terms, which appear only in equations (20) and (21), do not interact. Thus, as in Sarris and Freebairn, expected equilibrium tariffs can be determined without considering the variances of α_i and γ_i.

Following Sarris and Freebairn, it is assumed that a set of observed tariffs, $\bar{t}$, are Cournot equilibrium tariffs, and weights are normalized by requiring that

$$W_{ci} + W_{pi} + W_{gi} = 3. \tag{23}$$

Equations (12), (13), and (23) can be expressed in matrix notation as

$$Hw = f, \tag{24}$$

where

$$H = \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ 1 & 1 & 1 \end{bmatrix}$$

$$w' = [W_c W_p W_g], \text{ and}$$

$$f' = [0\ 0\ 3].$$

In matrix H,

$$h_{11} = \frac{X_{3i}}{\beta_i}[\alpha_i - \beta_i P^f + \bar{t}_i^d X_{3i} + \bar{t}_i^s X_{1i} + \beta_i R_i] \tag{25}$$

$$h_{12} = \frac{X_{1i}}{\delta_i}[\gamma_i + \delta_i P^f + \bar{t}_i^d X_{1i} + \bar{t}_i^s X_{2i} - \delta_i R_i] \tag{26}$$

$$h_{13} = \alpha_i - \beta_i P^f + 2\bar{t}_i^d X_{3i} + 2\bar{t}_i^s X_{1i} + \beta_i R_i \tag{27}$$

$$h_{21} = \frac{X_{1i}}{\beta_i}[\alpha_i - \beta_i P^f + \bar{t}_i^d X_{3i} + \bar{t}_i^s + \beta_i R_i] \tag{28}$$

$$h_{22} = \frac{X_{2i}}{\delta_i}[\gamma_i + \delta_i P^f + \bar{t}_i^d X_{1i} + \bar{t}_i^s X_{2i} - \delta_i R_i] \tag{29}$$

$$h_{23} = \gamma_i + \delta_i P^f + 2\bar{t}_i^d X_{1i} + 2\bar{t}_i^s X_{2i} - \delta_i R_i, \tag{30}$$

where

$$R_i = \frac{\Sigma_{j\neq i}(t_j^d \beta_j - t_j^s \delta_j)}{\Sigma_j^n(\beta_j + \delta_j)}. \tag{31}$$

Hence,

$$w = H^{-1}f. \tag{32}$$

The models were used to recalculate the results of Sarris and Freebairn. First, tariffs were calculated assuming an equally weighted welfare function ($W_{ci} = W_{pi} = W_{gi} = 1$). They are presented in table 1. With market power considered, it is clear that free trade (i.e., zero tariffs) is not the optimal policy if weights are equal. However, with equal weights, it is optimal to set P^d and P^s at the same level. All importers have a positive optimal tariff, while all exporters would maximize welfare by imposing an export tax. For the United States, the optimal tax is quite large, reflecting the degree of market power possessed by that country. Thus, while the United States appeared to be conducting an evenhanded policy in the base period (in the sense that producer and consumer prices equaled the world benchmark price), it was in fact favoring producers by not imposing the optimum tax.

Second, as an alternative it was assumed that the tariff structure observed in the base period was the outcome of a Cournot process, and corresponding welfare weights were calculated. The revised results are presented in table 1. If the assumption of a Cournot equilibrium process is realistic, the implicit welfare weights indicate the policy biases of different countries. The major exporters, except Argentina, favor their producers. This is reflected in producer weights in excess of one. The weights calculated here differ from those of Sarris and Freebairn by a greater margin as market power (as reflected by the equilibrium tariffs) increases. They underestimate producer weights in exporting countries and overestimate them in importing countries.

The results show that Sarris and Freebairn's simplifying assumption of no market power significantly affects the estimates of optimal policies and weights. The contribution of this comment is to show how strategic interactions can be more fully incorporated into the analysis.

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