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Optimal Retaliation in International Commodity Markets

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Retaliation and other strategic trade policies can be readily observed in world commodity markets. Strategic behaviour can be analysed with game-theoretic models. Game theory is used to assess the effects of retaliation, given that traders assume that rivals will respond to any policy change. Estimates of expected responses are obtained for each trading bloc, and are included in regional welfare functions. These are used to derive a market-clearing global equilibrium in which domestic prices, trade flow and welfare distribution in each region are determined. Market power among importers relative to exporters determines the effect of changes in expectations of retaliation on optimal trade policies and trade flows. The analysis is applied to a twenty-one region linear wheat trade model.

1. Introduction

International commodity markets have most commonly, although not exclusively, been analysed with the use of spatial equilibrium models in which international trade is assumed to be perfectly competitive (Kolstad and Burris 1986, p.28). In these models the combined effects of government intervention and market power are ignored or treated as exogenous. But government intervention (in the European Community [EC], the United States [US] and Japan for example) significantly influences world trade. There exist relatively few traders on one or both sides of the market. In the grains trade, three or four countries supply the bulk of all exports, and exert varying degrees of market power.

The influence of government has long been recognised, and recently attempts have been made to identify the determinants of government action (Rausser, Lichtenberg and Lattimore 1982). One approach to endogenising government policy highlights domestic political factors, such as the relative bargaining strength of various pressure groups (Sarris and Freebairn 1983). A second method involves the assumption that governments act to coordinate consumers or producers so that they may exercise market power. In spite of recent theoretical developments in these areas, few empirical models have endogenised government's role in the price formation process.

By assuming competitive behaviour, market power is ignored. However, when a country possesses market power, it is unlikely that such power would go unused. It is also reasonable to suppose that some form of retaliation can be expected when the imposition of a trade policy harms other traders. Examples of retaliatory behaviour can also be seen in the international wheat, meat, wine and steel markets.

Retaliation and other strategic trade policies cannot readily be analysed by competitive market models. Policies which appear to be welfare reducing may lead to a change in rival suppliers' policies and result in longer-run welfare gains. The few models that have incorporated retaliation are based on the assumption that traders do not expect rivals to vary their policy (that is, retaliate). Vanzetti and Kennedy (1988a) examined the effects of

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retaliation assuming that traders did not expect rivals to retaliate. The observed pattern of trade flows and prices was explained by deriving and estimating weights for producer and consumer/taxpayer groups in an unequally weighted welfare function. Vanzetti and Kennedy (1988b) subsequently expanded these results to include differential domestic prices (for consumers and producers) and welfare weights for three groups (with consumers and taxpayers treated separately). Here it is assumed that, when setting a policy, traders do expect some retaliation. This expectation affects optimum policies, trade flows and welfare. It will be shown that models which assume zero expected retaliation (or zero conjectural variations) may result in incorrect estimates of tariffs and welfare losses.

The general objective of this paper is to present a framework for analysing strategic behaviour (including non-zero conjectural variations) in international trade. Of particular interest is the impact of conjectural variations on optimum policies - the direction and extent to which tariffs change when the expectations of retaliation change.

To assess the impact of various conjectures, a simple linear trade model is derived, with import tariffs and export taxes/subsidies as the policy instruments. Initially, 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 implicit function theorem. Once estimated, these are used to derive optimum tariffs following an exogenous exchange rate change. This conjectural variations equilibrium is then compared to the corresponding Cournot-Nash equilibrium. For illustrative purposes, the analysis is applied to a 21 region wheat trade model, using data for the base period 1978-79 to 1979-80.

A brief review of the Cournot-Nash and conjectural variations equilibria is contained in the next section. Section 3 contains a review of the way in which other authors have tackled conjectural variations in trade models. In Section 4 a derivation of a simple one-commodity linear trade model is presented. The optimum tariff and conjectural variations formulae are derived. The alternative Cournot-Nash and conjectural variations solution concepts and algorithms are described later in the section. Results and the implications of the analysis are discussed in Section 5.

2. Game-theoretic Equilibria

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.

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 so-called Bertrand model 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 shortsighted at best, in that rivals are expected not to react, although this expectation is repeatedly falsified.

2.1 Conjectural variations

The conjectural variations model is a more general version of the Cournot model. 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 (Nelson and McCarl 1984). 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), the conjectural variations model contains an implicitly dynamic adjustment process, and is in fact similar to a repeated game model (McMillan 1986). However, the dynamics are not specified, since there is no discounting in the model. The time period involved is captured in the magnitude of the elasticities.

3. Previous Attempts to Model Conjectural Variations

3.1 Historical perspective

The concepts of strategic behaviour in industrial organisation can be related to the problem of retaliation in international trade. 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 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 1985, p.234).

Panchamukhi (1961) showed that Johnson's and Gorman's analyses are similar to a two-person non-zero sum game, opening the way for game-theoretic analysis in this area. McMillan (1986) noted 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 1967), labour markets (Batra 1977), and domestic distortions (Jones 1987).

The refinements described so far do not address the problem of non-zero expectations of retaliation. However, as noted previously, 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) took a somewhat *ad hoc* approach to this problem. Using a static two-country, two-commodity model, they imposed arbitrary conjectures and derived 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 arrived 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.

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 tariffs and taxes.

3.2 Grain trade models

In the applied area a number of modellers of imperfect competition have imposed arbitrary or ad hoc assumptions regarding expected response. McCalla (1966), in his cooperative duopoly model, had each duopolist accurately predicting how others would react to its policies within a given price-quantity band. Taplin (1969) maintained that the US followed the price leader Canada in its price setting. Constant market shares were assumed. A stable oligopoly solution resulted from a kinked demand curve.

Alaouze, Watson and Sturgess (1978) proposed 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 US and the price leader, Canada. When market shares are threatened, a limited price war is initiated, forcing Australia to restrain its exports. The authors identified the conditions under which the triopoly might degenerate into a price war, without specifying the role of expectations in the price formation process.

Carter and Schmitz (1979) postulated that an EC-Japan duopsony determined trade and prices. Schmitz, McCalla, Mitchell and Carter (1981) expounded this notion at greater length. In essence, 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) examined the potential for export cartels among the major exporters in the wheat trade. They concluded 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.

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) suggested 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.

These models of cooperative behaviour introduce possibilities of cheating, deterrence and side-payments, and increases the number of possible solutions. The solutions depend more on the assumption regarding collusive behaviour than on the nature of retaliation.

Karp and McCalla (1983) developed a dynamic difference game model of the world corn market. This model allows interaction between both exporters and importers, in contrast to some earlier models, and introduces time into the analysis. Reaction functions, showing how each country's tariff is influenced by other tariffs, are endogenously determined in the model. Traders adjust their policies over time depending on the behaviour of their rivals. However, this is not a conjectural variations model.

Kolstad and Burris (1986) used a nonlinear complementarity programming approach to compute spatial equilibrium in oligopolistic or oligopsonistic markets. They showed how conjectural variations estimates can be utilised; however, they made the Cournot assumption of zero conjectural variations.

Perhaps the most impressive attempt to incorporate conjectural variations is that of Paarlberg and Abbott (1986). They assumed policymakers hold conjectures regarding the slope of the excess demand function (response function), and derived 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, short run 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.

Many of the models of the grain trade in which market power is assumed are also based on the existence of cooperative behaviour. Of the noncooperative models, that of Paarlberg and Abbott (1986) is most similar to the work presented here. In this paper a revealed preference methodology is used to estimate aggregated conjectures. This work is similar to that of Vanzetti and Kennedy (1988a,b) in which welfare weights were estimated assuming observed tariffs were at their Cournot equilibrium levels. Here, the Cournot assumption of zero conjectures is dropped, and conjectures are estimated from observed tariffs. However, each country is assumed to have a welfare function with all interest groups weighted equally.

4. Theoretical Framework

This section contains a discussion of the underlying assumptions and derivation of a game-theoretic trade model. Two game-theoretic solutions, the Cournot-Nash and conjectural variations, are then described.

4.1 Assumptions

Important assumptions of the model requiring comment are: noncooperative behaviour; linear and deterministic supply and demand schedules; welfare optimisation; use of trade taxes as a control variable; static equilibrium; product homogeneity; zero cross-commodity effects and stockholding.

4.1.1 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.

4.1.2 Linear supply and demand

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. 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 counter-intuitive effect. Furthermore, a linear curve is likely to overstate the reduction in consumer surplus due to a price increase. These factors need to be borne in mind when interpreting the results, particularly if price changes are substantial.

4.1.3 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. 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.

4.1.4 Welfare optimisation

The strategy followed by each player involves optimising a welfare function, in which one agent per country or region sets trade taxes so as to maximise the sum of consumer and producer surplus and tax revenue. This assumes that the conflicts between the various groups have been resolved before the policymaker sets the tariff or tax. It is assumed that purchases 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 macroeconomic effects are ignored.

4.1.5 Tariffs as decision variable

A (positive or negative) unit tariff¹ 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

¹The term 'tariff' is sometimes used to refer to export taxes in addition to import taxes. Export taxes are expressed as negative tariffs.

advantage that the unit tariff can represent a range of policy instruments which result in an additive differential between world and domestic prices. As domestic consumers and producers may differ, each policymaker has two decision variables.

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.

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, p.40) noted that a joint consumer subsidy and producer tax will have a similar effect as an export tax. 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.

4.1.6 Static equilibrium

The model presented here is static. 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.

4.1.7 Product homogeneity and cross-commodity effects

In the empirical analysis, wheat is treated as an homogeneous product. 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. It is assumed that the cross-commodity effects, due to both retaliation and substitution, are insignificant.

4.1.8 Stockholding

Stocks are assumed to remain unchanged. In a static, deterministic model, there are no supply and demand fluctuations to even out, and therefore no reason to hold stocks.

Thus far in this section the nature of the game-theoretic model to be developed has been outlined. Next, a linear model is specified and equations for the optimum tariff for the Cournot and conjectural variations solutions are derived.

4.2 Linear trade model

Once demand and supply equations and equilibrium conditions are specified, a welfare function is derived for each trader. The solution method involves calculating the first order conditions to maximise these welfare functions. The reaction functions, showing how each country reacts to tariffs imposed by others, can then be derived. The functions can be solved simultaneously to obtain the equilibrium set of tariffs.

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

$$D_i = \alpha_i - \beta_i P_i^d \quad (1)$$

$$S_i = \gamma_i + \delta_i P_i^s, \quad (2)$$

where D_i and S_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 $\alpha_i, \beta_i, \gamma_i$ and δ_i refer to the usual intercept and slope parameters, which are all non-negative. To keep the algebra to a minimum, there are no additive disturbance terms in (1) and (2). It is argued later that this does not lead to a bias in the estimates of expected tariffs.

Assuming no change in stocks, and therefore market clearance:

$$\sum_i^n (D_i - S_i) = 0. \quad (3)$$

The market clearing free-trade price is:

$$P^f = \frac{\sum_i^n (\alpha_i - \gamma_i)}{BD}, \quad (4)$$

where

$$BD = \sum_i^n (\beta_i + \delta_i). \quad (5)$$

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

$$P^w = \frac{\sum_i^n (\alpha_i - \gamma_i - \beta_i t_i^d - \delta_i t_i^s)}{BD}, \quad (6)$$

where

$$t_i^d = P_i^d - P^w, \quad (7)$$

$$t_i^s = P_i^s - P^w. \quad (8)$$

With linear schedules, the total welfare function to be maximised for country i is:

$$W_i = CS_i + PS_i + TR_i, \quad (9)$$

with

$$CS_i = \frac{D_i^2}{2\beta_i}, \quad (10)$$

$$PS_i = \frac{S_i^2 - \gamma_i^2}{2\delta_i}, \quad (11)$$

$$TR_i = t_i^d D_i - t_i^s S_i. \quad (12)$$

CS_i , PS_i and TR_i refer to consumer surplus, producer surplus², and tariff revenue respectively. D_i and S_i now depend on t_j^d and t_j^s for all j .

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.

$$\begin{aligned}\frac{\partial W_i}{\partial t_i^d} &= \frac{2D_i}{2\beta_i} \frac{\partial D_i}{\partial t_i^d} + \frac{2S_i}{2\delta_i} \frac{\partial S_i}{\partial t_i^d} + D_i + t_i^d \frac{\partial D_i}{\partial t_i^d} - t_i^s \frac{\partial S_i}{\partial t_i^d}, \\ &= D_i(F_i - 1) + S_i(-F_i) + D_i + t_i^d(F_i\beta_i - \beta_i) - t_i^s(-\delta_i F_i), \\ &= F_i(D_i - S_i + t_i^d\beta_i + t_i^s\delta_i) - t_i^d\beta_i,\end{aligned}\tag{13}$$

where

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

Z_{ji}^{dd} refers to the change in the consumer tariff in country j in response to a change in the consumer tariff in country i . Likewise, Z_{ji}^{sd} denotes the response in the producer tariff in country j to a change in the consumer tariff in country i .

From (1), (2), (4), (5), (6), (7) and (8) it follows that

$$\begin{aligned}D_i - S_i &= \alpha_i - \gamma_i - (\beta_i + \delta_i)P^f + t_i^d\beta_i e_i + t_i^s\delta_i e_i \\ &\quad + e_i \sum_{j \neq i} (\beta_j t_j^d + \delta_j t_j^s) - \beta_i t_i^d - \delta_i t_i^s,\end{aligned}\tag{14}$$

where

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

Equation (13) can now be rewritten as

$$\frac{\partial W_i}{\partial t_i^d} = F_i(\alpha_i - \gamma_i - (\beta_i + \delta_i)P^f + e_i \sum_{j \neq i} (t_j^d\beta_j + t_j^s\delta_j)) - t_i^d\beta_i \tag{15}$$

² Equation (11) 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.

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

$$\begin{aligned}\partial W_i / \partial t_i^s &= \frac{2D_i}{2\beta_i} \frac{\partial D_i}{\partial t_i^s} + \frac{2S_i}{2\delta_i} \frac{\partial S_i}{\partial t_i^s} + t_i^d \frac{\partial D_i}{\partial t_i^s} - S_i - t_i^s \frac{\partial S_i}{\partial t_i^s} \\ &= G_i (\alpha_i - \gamma_i - (\beta_i + \delta_i) P^f + e_i \sum_{j=1}^n (t_i^d \beta_j + \delta_j t_j^s)) - t_i^s \delta_i\end{aligned}\quad (16)$$

where

$$\begin{aligned}G_i &= (\delta_i + \sum_{j=1}^n (\beta_j Z_{ji}^{dd} + \delta_j Z_{ji}^{sd})) / BD, \\ Z_{ji}^{ds} &= \frac{\partial t_j^d}{\partial t_i^s}, \\ Z_{ji}^{ss} &= \frac{\partial t_j^s}{\partial t_i^s}.\end{aligned}$$

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

$$t_i^d = \frac{-F_i(\alpha_i - \gamma_i - (\beta_i + \delta_i) P^f + e_i \delta_i t_i^s + e_i \sum_{j=1}^n (\beta_j t_j^d + \delta_j t_j^s))}{F_i e_i \beta_i - \beta_i}, \quad (17)$$

$$t_i^s = \frac{-G_i(\alpha_i - \gamma_i - (\beta_i + \delta_i) P^f + e_i \beta_i t_i^d + e_i \sum_{j=1}^n (\beta_j t_j^d + \delta_j t_j^s))}{G_i e_i \delta_i - \delta_i}. \quad (18)$$

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

$$At = g \quad (19)$$

where

$$\begin{aligned}t' &= [t_1, \dots, t_n, t_1^s, \dots, t_n^s] \\ &= [t_1^d, t_1^s, t_2^d, t_2^s, \dots, t_n^d, t_n^s]\end{aligned}$$

and

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

Equation (19) can be solved by matrix inversion to provide equilibrium tariffs

$$t^* = A^{-1}g \quad (20)$$

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.

4.3 The Cournot-Nash solution as a special case

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

$$Z_{ji}^{dd} = Z_{ji}^{ss} = Z_{ji}^{sd} = Z_{ji}^{ds} = 0 \quad \text{for } j \neq i, \quad (21)$$

$$Z_{ii}^{ds} = Z_{ii}^{sd} = 0, \quad (22)$$

$$Z_{ii}^{dd} = Z_{ii}^{ss} = 1. \quad (23)$$

F_i and G_i are thus

$$F_i = \beta_i / BD, \quad (24)$$

$$G_i = \delta_i / BD. \quad (25)$$

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 more general conjectural variations solution is able to do this.

4.4 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 (20) can be used to obtain a conjectural variations solution, with equation (21) 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 equal 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:

$$\frac{dt_j}{dt_i} = \sum_{k=1}^n \frac{\partial t_j}{\partial t_k} \frac{\partial t_k}{\partial t_i}. \quad (26)$$

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 counter-factual 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 (17) and (18), all each country i has to estimate is F_i and G_i , (defined following equations (13) and (16) respectively) which are the weighted sums 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 Vanzetti and Kennedy (1988b) to estimate a weighted welfare function. The expressions for F_i and G_i are derived from the first order conditions:

$$F_i = \frac{\bar{t}_i^d \beta_i}{\alpha_i - \gamma_i - (\beta_i + \delta_i)P^f + e_i \sum_{j=1}^n (\beta_j \bar{t}_j^d + \delta_j \bar{t}_j^s)}, \quad (27)$$

$$G_i = \frac{\bar{t}_i^s \delta_i}{\alpha_i - \gamma_i - (\beta_i + \delta_i)P^f + e_i \sum_{j=1}^n (\beta_j \bar{t}_j^d + \delta_j \bar{t}_j^s)}. \quad (28)$$

where \bar{t}_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.

4.5 Conjectures and optimal tariffs

The expressions for Z_{ji} and t_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

$$\frac{\partial t_i^d}{\partial t_j^d} = \frac{-F_i e_i \beta_j}{F_i e_i \beta_i - \beta_i}, \quad (29)$$

$$\frac{\partial t_i^d}{\partial t_j^s} = \frac{-F_i e_i \delta_j}{F_i e_i \beta_i - \beta_i}, \quad (30)$$

$$\frac{\partial t_i^d}{\partial F_i} = \frac{-\beta_i(\alpha_i - \gamma_i - (\beta_i + \delta_i)P^f + e_i\delta_i t_i^s + e_i \sum_{j=1}^n (\beta_j t_j^d + \delta_j t_j^s))}{(F_i e_i \beta_i - \beta_i)^2}, \quad (31)$$

$$\frac{\partial F_i}{\partial t_i^d} = \frac{\beta_i(\alpha_i - \gamma_i - (\beta_i + \delta_i)P^f + e_i(\sum_{j=1}^n \beta_j \bar{t}_j^d + \sum_{j=1}^n \delta_j \bar{t}_j^s))}{(\alpha_i - \gamma_i - (\beta_i + \delta_i)P^f + e_i \sum_{j=1}^n (\beta_j \bar{t}_j^d + \delta_j \bar{t}_j^s))^2}. \quad (32)$$

Equations (29) and (30) 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. A trade war between importers will escalate from the initial tariff. The 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 (31) 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 (27) and (28), and equation (20) 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

$$\beta'_i = \beta_i \rho, \quad (33)$$

$$\delta'_i = \delta_i \rho, \quad (34)$$

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.

5. Application to 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 section.

5.1 Data

The data used here are derived from those used by Sarris and Freebairn (1983) and are presented in Table 1. The twenty one regions are similar (with some aggregations) 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. Eastern Europe, the USSR, China, East

Table 1: Base Simulation Data 1978-79 to 1979-80

Region	S (mt)	D (mt)	(D - S) (mt)	t^s (US\$/t)	t^d (US\$/t)	Es	Ed	W (US\$m)
United States	53.25	22.40	-30.8	0.00	0.00	0.80	0.60	7997
Canada	19.45	5.15	-14.3	0.00	0.00	0.68	0.40	3045
Australia	17.18	3.00	-14.2	0.00	17.00	0.40	0.40	2879
Argentina	7.95	4.35	-3.6	-35.00	-35.00	0.48	0.20	2207
South Africa	1.95	1.70	-0.2	0.00	17.00	0.48	0.28	794
EC	46.30	41.25	-5.0	63.00	63.00	1.40	0.80	8449
Other Western Europe	10.15	10.30	0.1	63.00	63.00	1.40	0.80	2105
Japan	0.45	6.15	5.7	585.00	42.00	0.40	0.88	961
Eastern Europe	0.00	4.15	4.1	0.00	0.00	0.00	0.40	820
USSR	0.00	7.55	7.5	0.00	0.00	0.00	0.60	994
China	0.00	7.40	7.4	0.00	0.00	0.00	1.00	585
Brazil	2.60	6.70	4.1	53.00	-8.00	0.60	0.48	1239
Central America and Other South America	3.75	9.85	6.1	12.00	12.00	0.60	0.68	1751
Egypt	1.90	6.96	5.1	-38.00	-38.00	0.48	0.68	595
Other North Africa and Middle East	25.60	35.39	9.8	42.00	42.00	0.16	0.48	12494
Other Africa	0.75	3.50	2.7	17.00	17.00	0.60	1.00	445
India	33.37	35.14	1.8	0.00	0.00	0.40	0.80	7688
Other South Asia	12.63	15.86	3.2	-34.00	-34.00	0.40	0.80	2372
South East Asia	0.10	1.40	1.3	-8.00	-8.00	0.40	0.40	264
East Asia	0.00	5.10	5.1	0.00	0.00	0.00	0.60	671
Rest of World	0.00	4.08	4.1	0.00	0.00	0.00	1.00	322
TOTAL			68.2					58680

Source: Sarris and Freebairn (1983).

S denotes production; D - consumption; D-S - net imports; t^s - producer tariff; t^d - consumer tariff; Es - supply elasticity; Ed - demand elasticity; W - welfare.

Asia and the “Rest of World” are treated as net trading entities. Supply functions are not specified for these traders. Sarris and Freebairn used short-run elasticities and obtained short-run equilibria. Because a conjectural variations solution can most sensibly be interpreted as a long-run equilibrium, the elasticities used in Sarris and Freebairn have been multiplied by four³ for use in this analysis. While there is a certain arbitrariness, the data appear suitable for illustrative purposes.

In the reference period, the world price is taken to be the United States price, *i.e.* \$US158. Total trade volume is 68.23 million tonnes, and global welfare, with the long-run elasticities, amounts to \$US58760m. Because of the linear nature of the model, the welfare levels are not very meaningful; welfare pertaining to the game-theoretic solutions is expressed in terms of percentage deviation from the free trade or Cournot-Nash levels.

5.2 Free trade solution

The following tables show domestic consumer and producer tariffs (the difference between domestic and world prices), trade volume and welfare levels. 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 2, 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.

If all tariffs were removed, given the data used here, world prices would rise from the base price level of \$US158 per tonne to \$US175 per tonne. Total trade volume would be 80.8 million tonnes, higher than the 68.2 million tonnes 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 million tonnes, chiefly because the EC goes from net exports to a balanced trade (see Vanzetti and Kennedy (1988a) 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 \$US59,787m, compared with \$US58,680m in the base period, a gain of 1.9 per cent. This is the potential benefit from complete trade liberalisation.

5.3 Cournot-Nash solution

The Cournot-Nash solution is shown in Table 3. Countries with the greatest market power (reflecting market share and relative elasticities) impose the greatest tariff or tax. For this reason, taxes on the export side tend to be greater than on the import side. Producer and consumer prices are the same in each case, although there are provisions in the model for discriminating between them. This is an intuitively appealing result, reflecting equal welfare weights on consumers, producers and taxpayers. Unequal weights would result in

³ Sarris and Freebairn (1983, p.221) divided some of their long-run elasticities by four.

Table 2: Tariffs, Trade and Welfare Under Free Trade

Region	Tariff	Trade	Welfare
	(US\$/t)	(mt)	(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 and Other South America	0.00	5.8	1645
Egypt	0.00	2.4	579
Other North Africa and 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
WORLD		80.8	59787

differential prices. With the imposition of tariffs, the world price rises to \$US178, marginally above the free trade level of \$US175. 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.

5.4 20 per cent US depreciation

The Cournot-Nash solution following a 20 per cent depreciation of the US dollar is shown in Table 4. Compared with the previous Cournot-Nash solution, world price has risen 20.2 per cent⁴, from \$US178 to \$US214, in spite of the increased trade flow. With the depreciation, the United States has increased its market share from 41.7 to 49.9 per cent, and its taxes have risen substantially, in US dollar terms, from \$20 to \$32. Welfare rises 17.6 per cent. American producers and taxpayers have benefitted at the expense of consumers.

At a global level, welfare has increased by 24 per cent in US dollar terms, reflecting the improved trade flow. As expected, competing exporters suffer diminished trade flow, but

⁴ This value is based on unrounded prices.

Region	Tariff		Trade	Welfare
	Consumer	Producer	(mt)	Deviation (per cent *)
	(US\$/t)	(US\$/t)		
United States	-19.71	-19.71	-30.8	0.13
Canada	-8.45	-8.45	-15.4	0.93
Australia	-7.85	-7.85	-14.6	0.98
Argentina	-2.96	-2.96	-5.6	0.51
South Africa	-0.19	-0.19	-0.4	0.00
EC	7.39	7.39	10.9	-0.48
Other West Europe	2.38	2.38	4.3	-0.45
Japan	3.36	3.36	6.3	-1.54
Eastern Europe	2.06	2.06	3.9	-1.20
USSR	3.65	3.65	6.9	-1.73
China	3.38	3.38	6.3	-3.23
Brazil	1.96	1.96	3.7	-0.76
Central America and Other South America	2.97	2.97	5.5	-0.72
Egypt	1.23	1.23	2.3	-0.86
Other North Africa and Middle East	6.34	6.34	11.5	-0.23
Other Africa	1.40	1.40	2.7	-1.51
India	-1.76	-1.76	-2.9	0.07
Other South Asia	-2.31	-2.31	-4.1	0.35
South East Asia	0.62	0.62	1.2	-1.23
East Asia	2.46	2.46	4.7	-1.87
Rest of World	1.86	1.86	3.5	-3.13
WORLD			73.8	-0.14

* Welfare is expressed as percentage deviation from free trade.

the higher US prices have enabled them to increase their taxes, and this has led to an increase in welfare exceeding the 20 per cent depreciation. Importers have also benefitted from the increased trade flow.

5.5 Conjectural variations trade war solution

The conjectural variation estimates are shown in Table 5 along with the post-depreciation conjectural variations solution. The conjectural variation estimates are prior to depreciation. $F_i - \beta_i / BD$ refers to changes in response to consumer prices. $G_i - \delta_i / BD$ refers similarly to producer prices. The estimates are not percentage changes; they are based on a unit change in t_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

Table 4: Cournot-Nash Equilibrium Following Depreciation

Region	Tariff		Trade	Welfare
	Consumer	Producer		
	(US\$/t)	(US\$/t)	(mt)	Deviation (per cent*)
United States	-31.65	-31.65	-39.6	18
Canada	-9.72	-9.72	-14.8	21
Australia	-9.18	-9.18	-14.4	21
Argentina	-3.39	-3.39	-5.3	23
South Africa	-0.20	-0.20	-0.3	25
EC	10.54	10.54	13.2	26
Other West Europe	3.23	3.23	4.9	27
Japan	4.12	4.12	6.5	31
Eastern Europe	2.50	2.50	4.0	29
USSR	4.47	4.47	7.1	31
China	4.22	4.22	6.6	37
Brazil	2.45	2.45	3.9	28
Central America and Other South America	3.76	3.76	5.9	28
Egypt	1.65	1.65	2.6	28
Other North Africa and Middle East	7.98	7.98	12.1	26
Other Africa	1.76	1.76	2.8	30
India	-1.09	-1.09	-1.5	25
Other South Asia	-2.21	-2.21	-3.3	24
South East Asia	0.76	0.76	1.2	29
East Asia	3.02	3.02	4.8	31
Rest of World	2.33	2.33	3.7	36
WORLD			79.2	24

* Welfare is expressed as percentage deviation from pre-depreciation Cournot-Nash level (Table 3).

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 5 can be compared with Table 4 to assess the impact of conjectural variations on prices, trade flow and welfare. Comparisons with earlier tables can be seen from Table 6. Assuming countries hold the same expectations of retaliation after depreciation as before, the resulting tariffs and trade flows are as shown in Table 5. 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 \$US178 is below the revised Cournot-Nash level of \$US214, because some exporters have lower, or zero, export taxes, and some importers have increased tariffs. With the fall in price, exporters are worse off, and most importers have gained. Global welfare at \$US72661m is down 2.2 per cent on the Cournot-Nash equivalent. These results illustrate

Table 5: Conjectural Variations Equilibrium Following Depreciation

Region	$F_i - \frac{\beta_i}{BD}$	$G_i - \frac{\delta_i}{BD}$	Tariff		Trade (mt)	Welfare Deviation (per cent *)
			Consumer (US\$/t)	Producer (US\$/t)		
United States	-0.053	-0.168	0.00	0.00	-38.0	1
Canada	-0.006	-0.042	0.00	0.00	-12.8	6
Australia	-0.012	-0.022	20.08	0.00	-13.4	5
Argentina	0.047	0.205	-38.56	-38.56	-3.2	15
South Africa	-0.228	-0.003	7.39	0.00	-0.1	24
EC	0.338	0.663	102.22	102.22	-6.6	15
Other West Europe	0.340	0.586	97.53	97.53	0.2	20
Japan	0.149	0.020	55.66	775.24	6.0	49
Eastern Europe	-0.005	0.000	0.00	0.00	4.3	49
USSR	-0.014	0.000	0.00	0.00	8.0	63
China	-0.023	0.000	0.00	0.00	8.1	96
Brazil	-0.050	0.087	-11.03	73.05	4.5	40
Central America and Other South America	0.051	0.017	16.80	16.80	6.8	42
Egypt	-0.478	-0.092	-58.00	-58.00	6.2	38
Other North Africa and Middle East	0.209	0.050	58.49	58.49	10.9	29
Other Africa	0.099	0.013	23.60	23.60	3.0	58
India	-0.089	-0.042	0.00	0.00	5.8	26
Other South Asia	2.078	0.827	14.71	14.71	-1.1	21
South East Asia	-0.025	-0.002	-10.49	-10.49	1.4	48
East Asia	-0.010	0.000	0.00	0.00	5.4	63
Rest of World	-0.013	0.000	0.00	0.00	4.5	96
WORLD					75.2	22

* Welfare is expressed as percentage deviation from pre-depreciation Cournot-Nash level (Table 3).

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 -\$US7.85. 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 from 13.4 to 12.9 million tonnes, but welfare would rise from \$US3336m to \$US3340m. Other exporters would benefit through increased trade flow. Trade flow from the US would increase from 38.04 to 38.8 million tonnes. On the importing side, conjectures, tariffs and trade would increase but welfare would fall. For example, the EC's conjectures would rise from 0.338 and 0.663 (see Table 5) to 0.340 and 0.667, and its tariffs would rise by \$US0.04. Trade flow would rise from 6.56 to 6.7 million tonnes, but welfare would fall from \$US10,314m to \$US10,300m.

A summary of the results is presented in Table 6. Each row corresponds to a solution in a

Table 6: Comparative Solutions			
Solution	Price (US\$/t)	Trade (mt)	Welfare (US\$m)
Base Period	158	68.2	58680
Free Trade	175	80.8	59787
Cournot-Nash	178	73.8	59701
Cournot-Nash (Post-Dep)	214	79.2	74285
Conjectural Variations (Post-Dep)	178	75.2	72661

particular table. Prices and welfare in the final two rows are in terms of the US dollar following depreciation.

6. Implications and Conclusions

These results confirm that if a country can influence the world price and if welfare weights are equal, the optimal policy for an importer is a positive tariff, and for an exporter a positive tax. In the absence of domestic distortions, it will be optimal to maintain producer and consumer prices at the same level.

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 to exceed tariff-ridden welfare levels in every case. However, because losers are not compensated (there are no side-payments), some countries may prefer the noncooperative trade war outcome to trade liberalisation. This supports the view that a successful outcome to multilateral trade negotiations may require side-payments, perhaps in the form of concessions on non-agricultural trade.

The impact of retaliation depends upon whether it occurs on the same side of the market. Retaliation between importers leads to increased tariffs, and a movement away from the free trade equilibrium. A similar result holds for exporters. However, if a change in tariffs leads only to changes in export taxes the resulting equilibrium will be closer to free trade. It is likely that both importers and exporters will respond. The combined effect is indeterminate, and depends on the relative market power of exporters and importers.

Likewise, 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.

Australia has limited influence as an exporting nation. Given the existence of strategic behaviour in the wheat market, the most appropriate policy 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 side-payments, 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 a commitment to it. Australia's present policy stance contains elements of each of these approaches.

Although limited, Australia does have some ability to influence the world price. If all other traders were playing their Cournot-Nash policy, Australia's best noncooperative policy would be a small export tax. An increase in this tax, perhaps due to a change in policymakers' preferences, would make it optimal for other exporters to increase their taxes, leading to a higher world price. Optimal tariffs would fall marginally.

A large trader, such as the US or the EC, has of course much more scope to behave strategically. As it can influence the world price, its behaviour can affect others. Thus, its threats carry much greater force. There may be some value in attempting to change other countries' conjectures by issuing threats or the occasional use of policies which may be welfare-decreasing in the short run. The use of export subsidies may possibly be seen in this fashion. 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 side-payments (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.

In this paper, a framework for analysing strategic behaviour is presented. While other authors have examined optimal tariffs, and a number have treated the world wheat market as an oligopoly, the contribution of this work involves the estimation of aggregated conjectures in a trade model in which policymakers set policy so as to maximise a welfare function. This provides a means of assessing the effects of changes in expectations of retaliation. Finally, the analysis is applied to a 21 sector trade model. Changes in expectations are shown to significantly influence the equilibrium trade flows, prices, tariffs and welfare.

References

ALAOUZE, C.M., WATSON, A.S. and STURGESS, N.H. (1978), "Oligopoly pricing in the world wheat market", *American Journal of Agricultural Economics* 60(2), 173-85.

BATRA, R.N. (1977), "Unemployment, tariffs and the theory of international trade", *Journal of International Economics* 43(3), 295-306.

BRESNAHAN, T.F. (1981), "Duopoly models with consistent conjectures", *American Economic Review* 71(5), 934-45.

CARTER, C., GALLINI, N. and SCHMITZ, A. (1980), "Producer-consumer trade-offs in export cartels: the wheat cartel case", *American Journal of Agricultural Economics* 62(4), 812-18.

CARTER, C. and SCHMITZ, A. (1979), "Import tariffs and price formation in the world wheat market", *American Journal of Agricultural Economics* 61(3), 518-22.

GARDNER, B. (1988), "Export policy, deficiency payments, and a consumption tax", *Journal of Agricultural Economics Research* 40(1), 38-41.

GORMAN, W.M. (1957-58), "Tariffs, retaliation and elasticity of demand for imports", *Review of Economic Studies* 25(1), 133-62.

HORWELL, D.J. (1966), "Optimum tariffs and tariff policy", *Review of Economic Studies* 33(1), 147-58.

JOHNSON, H.G. (1953-54), "Optimum tariffs and retaliation", *Review of Economic Studies* 21(2), 142-53.

JONES, A.P. (1987), "Optimal tariffs, retaliation, and cooperation in the presence of domestic distortions", *Discussion Paper Series A:87/5*, School of Economic Studies, University of Leeds.

JONES, R.W. (1967), "International capital movements and the theory of tariffs and trade", *Quarterly Journal of Economics* 81(1), 1-38.

KALDOR, N. (1940), "A note on tariffs and the terms of trade", *Economica* 7(2), 377-80.

KAMIEN, M.I. and SCHWARTZ, N. (1983), "Conjectural variations", *Canadian Journal of Economics* 16(2), 192-211.

KARP, L.S. and McCALLA, A.F. (1983), "Dynamic games and international trade: an application to the world corn market", *American Journal of Agricultural Economics* 65(4), 641-50.

KOLSTAD, C.D. and BURRIS, A.E. (1986), "Imperfectly competitive equilibria in international commodity markets", *American Journal of Agricultural Economics* 68(1), 27-36.

KUGA, K. (1973), "Tariff retaliation and policy equilibrium", *Journal of International Economics* 39(4), 351-66.

McCALLA, A.F. (1966), "A duopoly model of world wheat pricing", *Journal of Farm Economics* 48(3), 711-27.

McMILLAN, J. (1986), *Game Theory in International Economics*, Harwood, London.

NELSON, C.H. and McCARL, B.A. (1984), "Including imperfect competition in spatial equilibrium models", *Canadian Journal of Agricultural Economics* 32(1), 55-70.

OTANI, Y. (1980), "Strategic equilibrium of tariffs and general equilibrium", *Econometrica* 48(4), 643-62.

PAARLBERG, P.L. and ABBOTT, P.C. (1986), "Oligopolistic behavior by public agencies in international trade: the world wheat market", *American Journal of Agricultural Economics* 68(3), 528-42.

PANCHAMUKHI, V.R. (1961), "A theory for optimal tariff policy", *Indian Economic Journal* 9(2), 178-98.

PERRY, M.K. (1982), "Oligopoly and consistent conjectural variations", *Bell Journal of Economics* 13(1), 197-205.

RAUSSER, G.C., LICHTENBERG, E. and LATTIMORE, R. (1982), "Developments in theory and empirical applications of endogenous government behaviour", in G.C. Rausser (ed.) *New Directions in Econometric Modeling and Forecasting in U.S. Agriculture*, North-Holland, New York.

RODRIGUEZ, C.A. (1974), "The non-equivalence of tariffs and quotas under retaliation", *Journal of International Economics* 4(2), 295-98.

ROJKO, A., REGIER, D., O'BRIEN, P., COFFING, A. and BAILEY, L. (1978), Alternative Futures For World Food in 1985 - Vol. 4, World GOL Model Analytical Report, *Foreign Agricultural Economic Report No. 146*, U.S. Department of Agriculture, Washington.

SARRIS, A.H. and FREEBAIRN, J. (1983), "Endogenous price policies and international wheat prices", *American Journal of Agricultural Economics* 65(2), 214-24.

SCHMITZ, A., McCALLA, A.F., MITCHELL, D.O. and CARTER, C. (1981), *Grain Export Cartels*, Ballinger, Cambridge, Massachusetts.

SCITOVSKY, T. (1942), "A reconsideration of the theory of tariffs", *Review of Economic Studies* 9(2), 89-110.

TAPLIN, J.H. (1969), "Demand in the world wheat market and the export policies of the United States, Canada and Australia", *Ph.D. Dissertation*, Cornell University.

THURSBY, M. and JENSEN, R. (1983), "A conjectural variation approach to strategic tariff equilibria", *Journal of International Economics* 14(1), 145-61.

TOWER, E. (1975), "The optimum quota and retaliation", *Review of Economic Studies* 42(4), 623-30.

VANZETTI, D.M. and KENNEDY, J.O.S. (1988a), "Retaliation in the international wheat trade", *Discussion Paper No. 9/88*, School of Economics, La Trobe University, Bundoora.

____ and ____ (1988b), "Endogenous price policies and international wheat prices: comment", *American Journal of Agricultural Economics* 70(3), 743-46.

WEYMARK, J.A. (1980), "Welfare optimal tariff revenues and maximum tariff revenues", *Canadian Journal of Economics* 13(4), 27-48.

WHALLEY, J. (1985), *Trade Liberalization among Major World Trading Areas*, MIT Press, Cambridge, Massachusetts.