Strategic Trade Policy With Competitive Storage

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33rd Annual Conference of the
Australian Agricultural Economic Society
Lincoln College, Canterbury, New Zealand.
7 - 9 February, 1989.

1 Introduction

In countries which have some influence over world agricultural prices, policymakers need to consider how other countries may react to a change in trade policy, and the time profile of the effects of the policy. Where more than one country can influence prices, there is potential for conflict. Such situations can be analysed with game theory. Where the effects of a policy are not instantaneous, or if there are production lags or other adjustment costs, a dynamic model is suitable. If the commodity in question is stored, changes in stock levels must also be considered. In this paper the strategic, intertemporal and stockholding aspects of trade policy determination are jointly considered in a dynamic game model with competitive storage.

This paper is an extension of earlier work on strategic trade policy in the absence of storage. In Vanzetti and Kennedy (1988a), the strategic effects of policy were analysed in a static framework. It was assumed that traders expected no retaliation from their rivals, although some response could be readily observed. The effects of a trade war on prices, tariffs and welfare distribution were assessed. Retaliatory behaviour was shown to be self-limiting, at least if traders were setting tariffs or taxes so as to maximise welfare. To explain the observed pattern of trade flows and prices, weights on the surplus attributed to producers and consumers-taxpayers were estimated. In Vanzetti and Kennedy (1988b), domestic prices were differentiated, and weights were estimated for three groups (with consumers and taxpayers treated separately). In a later paper (Vanzetti and Kennedy 1988c), the assumption that rivals were expected not to retaliate was dropped. This modified the most appropriate policy, and led to different trade war outcomes.

The need for a dynamic model results from the lags in production and policy response. For most agricultural crops there is a lag between the decision to produce and the harvest. Furthermore, price expectations may be based on past prices. Likewise, policymakers may be constrained in their responses by various institutional impediments, such as the need to consult with a range of interest groups. Trading countries do not necessarily

*The authors thank, with the usual caveat, Greg O'Brien, Tony Chisholm and Rod Maddock for helpful comments and suggestions.

respond instantaneously to changes in rivals' trade policies. Dynamic models allow for intertemporal combinations of behaviour that cannot be captured in a static model. A dynamic game model was presented in Vanzetti and Kennedy (1988d). The effects on prices, tariffs and welfare of changes in the perceived time horizon, the discount rate and an American drought were considered. In Vanzetti (1988), welfare weights were estimated using more recent data, and the dynamic trade war solutions were estimated assuming that traders were maximising weighted welfare functions.

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. Given fluctuating prices, it is reasonable that private, competitive storage would play 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 paper is to incorporate storage into a dynamic game model. Of interest is the effect of storage 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 countries hold stocks?

In previous papers, the dynamic game model involved 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 this 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[1]. Thus, a different approach is necessary. In this paper, 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.

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.

The welfare effects of stabilisation are well known. Massell (1969) showed that with

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

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 in fact 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, 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.

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 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) has demonstated the effectiveness of free trade compared to 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 stabilsation 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) examined the relationship between domestic policies and international storage policies. They were concerned to show what sort of storage policy would offset the domestic policies which destabilised the world price. They defined 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 demonstrated that stability could be attained by varying domestic policies to counter stochastic shocks. However, they were 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 to the costs of financing the buffer stocks.

Shei and Thompson (1977) examined the relationship between domestic policies and price stability, utilising a quadratic programming model. They came to the now familiar conclusion that domestic policies, which insulate domestic markets, are the source of much instability in the world market.

This point was supported by Johnson (1975) who argued 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) argued 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.

Newbery addressed 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 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.

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.

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.

3 A Multiperiod QP Model With Tariffs and Storage

In this section a simple, dynamic, linear trade model is described. A quadratic programming procedure, which is used to solve simultaneously for the welfare-maximising levels of tariffs (or subsidies or taxes), stocks, production, consumption and world price is then explained.

Consider an international market in which there is no cooperation between policymakers in each country or region and demand and supply curves are linear and deterministic. Tariffs (the domestic-world price differential) are set so as to maximise a welfare function subject to world price and the tariffs 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. Furthermore, assume supply is a function of lagged prices and tariffs, and that the product is homogeneous. These assumptions are discussed in detail in Vanzetti and Kennedy (1988d).

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.

The model will now be described in detail. The supply and demand intercept and slope terms are derived from the price, quantity and elasticity data. Once these are obtained, demand and supply in each region can be expressed as

$$D_{it} = \alpha_i - \beta_i(P_t + x_{it}), \tag{1}$$

$$S_{it} = \gamma_i + \delta_i(P_t^e + x_{it-1}), \tag{2}$$

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 in period t and the price producers expect to receive; 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 (with the exception of α_i) are non-negative and assumed constant across all time periods. α_i is assumed to increase at 3 per cent per period.

Let

$$P_t^e = P_{t-1} + \epsilon_i(P_{t-1} - P_{t-2}) \tag{3}$$

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 is zero, and hence suppliers respond to price lagged one period only, and to 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 (2) and (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 there own countries 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.)

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.

$$\begin{aligned} P_t + k &= \psi P_{t+1} \quad if \quad I_t \geq 0 \quad (4) \\ P_t + k &\geq \psi P_{t+1} \quad if \quad I_t = 0 \end{aligned}$$

(5)

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

$$\Sigma_{i=1}^n(D_{it} - S_{it}) + \Sigma_{i=1}^n I_{it} - \Sigma_{i=1}^n I_{it-1} = 0. \tag{6}$$

The market clearing free-trade price is

$$P_t^f = \frac{1}{\Sigma_{i=1}^n \beta_i}[\Sigma_{i=1}^n(\alpha_i - \gamma_i) - \Sigma_{i=1}^n \delta_i(1+\epsilon_i)P_{t-1} - \Sigma_{i=1}^n \delta_i \epsilon_i P_{t-2} + \Sigma_{i=1}^n I_{it} - \Sigma_{i=1}^n I_{it-1}]. \tag{7}$$

With tariffs, the market clearing world price becomes

$$P_t = P_t^f - \frac{\Sigma_{i=1}^n(\beta_i x_{it} + \delta_i x_{it-1})}{\Sigma_{i=1}^n \beta_i}. \tag{8}$$

Once the world price and all tariffs and stocks are determined, welfare can be calculated. The total welfare function to be maximised for country i over the time horizon is

$$W_i = \Sigma_{t=1}^T \psi^t W_{it}. \tag{9}$$

In each period,

$$W_{it} = CS_{it} + PS_{it} + TR_{it} + NSG_{it} \tag{10}$$

with

$$\begin{aligned}
CS_{it} &= \frac{D_{it}^2}{2\beta_{it}}, && (11)\\
PS_{it} &= \frac{S_{it}^2 - \gamma_{it}^2}{2\delta_{it}} + S_{it}(P_t + x_{it} - P_t^e - x_{it-1}), && (12)\\
TR_{it} &= (D_{it} - S_{it})x_{it}, && (13)\\
NSG_{it} &= I_t(P_t - P_{t-1}) - k_t I_t. && (14)
\end{aligned}$$

CS_{it}, PS_{it}, TR_{it} and TSC_{it} refer to consumer surplus, producer surplus[2], 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

$$W_{it} = p_{it}' y_{it} + \frac{1}{2} y_{it}' K_{it} y_{it} \tag{15}$$

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. (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.)

The welfare function is maximised subject to the constraints implied by the demand, supply and market clearance equations (1-4).

$$Ay = b \tag{16}$$

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

[2]Equation (12) for PS_{it} assumes γ exceeds zero, as is the case for all data used here. If γ is negative, the constant term $-\gamma_{it}^2/2\delta_{it}$, is not included. Note that it drops out upon differentiation.

$$K_i = \begin{bmatrix}
\frac{1}{\beta_1} & & & & & & \cdots & & & & & & 1 & & & -1 & & \\
& \frac{1}{\delta_1} & & & & & \cdots & & & 1 & & & & & & & & \\
& & \frac{\psi}{\beta_1} & & & & \cdots & & & & & & & \psi & & & -\psi & \\
& & & \frac{\psi}{\delta_1} & & & \cdots & & & -\psi(1+\epsilon) & \psi & & -\psi & & & \psi & & \\
& & & & \frac{\psi^2}{\beta_1} & & \cdots & & & & & & & & \psi^2 & & & -\psi^2 \\
& & & & & \frac{\psi^2}{\delta_1} & \cdots & & & \psi^2\epsilon & -\psi^2(1+\epsilon) & \psi^2 & & -\psi^2 & & & \psi^2 & \\
\vdots & & & & & & \vdots & & & & & & & & & & & \\
& & & & & & & & & -\psi & \psi^2 & & & & & & & \\
& & & & & & & & & & -\psi^2 & \psi^3 & & & & & & \\
& & & & & & & & & & & & & & & & & \\
& 1 & & -\psi(1+\epsilon) & & \psi^2\epsilon & \cdots & -\psi & & & & & & & & & & \\
& & & \psi & & -\psi^2(1+\epsilon) & \cdots & \psi^2 & -\psi^2 & & & & & & & & & \\
& & & & & \psi^2 & \cdots & & \psi^3 & & & & & & & & & \\
1 & & & -\psi & & & & & & & & & & & & & & \\
& & \psi & & & -\psi^2 & & & & & & & & & & & & \\
& & & & \psi^2 & & & & & & & & & & & & & \\
-1 & & & \psi & & & & & & & & & & & & & & \\
& & -\psi & & & \psi^2 & & & & & & & & & & & & \\
& & & & -\psi^2 & & & & & & & & & & & & &
\end{bmatrix}_{(nxn)}$$

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

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^f and γ_i^f. 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.

$$y_i = \begin{bmatrix} D_{11} \\ S_{11} \\ D_{12} \\ S_{12} \\ D_{13} \\ S_{13} \\ D_{21} \\ S_{21} \\ D_{22} \\ S_{22} \\ D_{23} \\ S_{23} \\ I_{11} \\ I_{12} \\ P_1 \\ P_2 \\ P_3 \\ x_{11} \\ x_{12} \\ x_{13} \\ x_{11}^e \\ x_{12}^e \\ x_{13}^e \end{bmatrix}_{(nx1)} \qquad p_i = \begin{bmatrix} 0 \\ -P_0 \\ 0 \\ \epsilon P_0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ -\psi k \\ -\psi^2 k \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}_{(nx1)}$$

$$b_i = \begin{bmatrix} \alpha_{11} & = & \alpha'_{11} \\ \gamma_1 & = & \gamma'_1 + \delta_1 P_0 \\ \alpha_{12} & = & \alpha'_{12} \\ \gamma_1 & = & \gamma'_1 - \delta_1 \epsilon P_0 \\ \alpha_{13} & = & \alpha'_{13} \\ \gamma_1 & = & \gamma'_1 \\ \alpha_{21} & = & \alpha'_{21} - \beta_2 x_{21} \\ \gamma_2 & = & \gamma'_2 + \delta_2 P_0 \\ \alpha_{22} & = & \alpha'_{22} - \beta_2 x_{22} \\ \gamma_2 & = & \gamma'_2 - \delta_2 \epsilon P_0 + \delta_2 x_{21} \\ \alpha_{23} & = & \alpha'_{23} - \beta_2 x_{23} \\ \gamma_2 & = & \gamma'_2 - \delta_2 x_{22} \\ -I_{21} & & \\ -I_{22} & & \end{bmatrix}_{(mx1)}$$

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

The programming problem is thus

$$Max \quad W_i = p'y + \frac{1}{2} y'Ky \tag{17}$$

$$s.t. \quad Ay = b \tag{18}$$

$$y \geq 0. \tag{19}$$

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 Cournot-Nash equilibrium is a point from which no player would want to move, given that all other players are playing their optimum strategies. The dynamic Cournot-Nash equilibrium is obtained by an iterative procedure. First, the optimal policy over the specified time horizon is found for country one, assuming all other countries have zero tariffs. This implies that P_0 is the free trade price for the first iteration. Next, country two's optimal tariffs are found taking into account country one'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 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.

4 The International Wheat Market

The analysis developed here can be suitably applied to the international wheat market. Wheat can be stored at reasonable cost, and market power exists on the supply side because of the small number of exporters. One of these, the United States, supplies up to half of the international market. 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 existence of state trading gives the many individual producers an opportunity to capture some of the monopoly rents. The market structure provides a reason for tariffs and taxes. The optimal policy for an importer with sufficient power to influence world prices is an import tariff. For an exporter, an export tax is optimal. Of course, trade policies take a variety of forms in addition to tariffs and taxes. While many policies can be considered in terms of tariff or subsidy equivalents, some policies which have equivalent effects at one world price may have differing effects at another. Tower (1975) has shown that tariffs and quotas may not be equivalent in the presence of retaliation. The results obtained here are consistent with the domestic-world price differential being composed entirely of a tariff or tax. In spite of this limitation, the data are seen as suitable to illustrate how the model may be applied.

Following presentation of the reference data, the optimal solution for the United States in the absence of retaliation is shown. The impact of storage, assuming other countries neither store nor set tariffs, on USA tariffs and the world price is examined. To show the effect of the option to store on market power, the Cournot-Nash solution without storage is compared with one in which the USA, the EC and Japan hold stocks.

4.1 The data

The quantity data were obtained from International Wheat Council statistics, as presented in IAC (1988). They pertain to the crop year 1985-86, the most recent data available. 1985-86 was not a representative year, being characterised by high stock levels and significant government intervention. This needs to be borne in mind when interpreting the results. The elasticities are from Sarris and Freebairn (1983), and are short-run. It is not possible to obtain empirical estimates for the supply and demand elasticities for the particular aggregation of rest-of-world used here. The parameters chosen are reasonable, and moderate variation does not change the results qualitatively.

In this 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. 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. This implies a weight of 0.7 on the one period lag and 0.3 on the two period lag. The real discount rate is set at three percent. 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 to the world price changes, and few if any stocks are held. With zero growth and a five per cent discount rate, stocks would only be held in the disequilibrium periods between free trade (period zero) and

[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.

Table 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: 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.

convergence (period 5). Once at the equilibrium, there would be no incentive to hold stocks, as the world price would be stable.

The reference period data is shown in Table 1. All price are in US$ terms. The world price is taken as $128/t, the US Gulf Hard Winter Wheat price.

4.2 Impact of stockholding on tariffs in absence of retaliation

In this model, the levels of stocks and tariffs in any given country are simultaneously determined, as policy makers 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 1, and in detail in Table 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 1. Impact of Stockholding

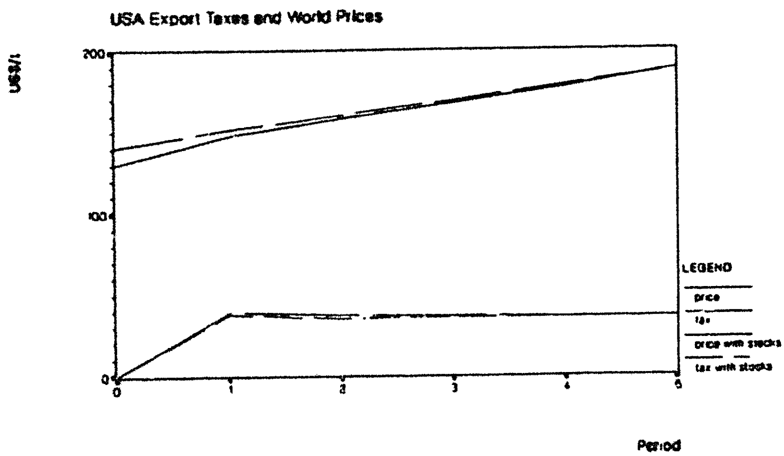

Table 2: Impact of Stockholding on USA Export Taxes and World Prices

Period	Without Stockholding		With Stockholding		
	Price US$/t	Tax US$/t	Price US$/t	Tax US$/t	Stocks mmt
0	130.20	0	140.23	0	4.92
1	147.46	39.26	151.86	37.65	9.18
2	158.33	37.40	159.89	35.43	11.84
3	167.42	36.51	168.94	35.59	13.42
4	177.58	35.74	178.42	35.93	14.43
5	188.18	35.58	188.07	36.18	14.58

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

Note firstly that 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.

In this deterministic model optimal stock levels are quite low, much lower than in reality. This illustrates that the need to hold stocks to eliminate price fluctuations due to factors other than stochastic shocks is minimal. In the real world, the USA holds stocks that might otherwise be held by other nations, and furthermore, public stockholding reflects policies aimed at supporting producer incomes, rather than pure price stabilisation.

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. This benefit often outweighs that due to price stabilisation per se. Wright and Williams (1984) maintain that this is an important and neglected feature of models of price stabilisation.

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 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 1.41 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 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.

The location of storage across regions is primarily dependent upon relative costs of storage. For the results presented in Table 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 to 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, not shown here, 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

Table 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	130.20	0.00	129.45	0.00	1.61
1	143.12	41.44	140.20	41.46	2.60
2	152.16	39.48	148.64	39.95	1.61
3	158.25	39.06	155.53	38.84	0.63
4	164.24	37.56	162.65	37.29	0.20
5	171.43	37.06	170.09	35.92	0.18

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

Table 4: Impact of Stockholding on Cournot-Nash Equilibrium

Solution with stockholding in parentheses

Region	Trade	Tariff	Stocks	Welfare
	mmt	US$/t	mmt	US$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: $153.23 ($151.02).

.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.

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 affect 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.

5 Implications and Conclusions

Before drawing implications from the results, it is prudent to note some limitations of the model. These include the linearity of the supply and demand functions, the validity of the elasticities, and the partial nature of the model, with no cross-commodity or intersectoral effects. The model can best be seen as illustrative of the usefulness of the technique.

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.

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.

Potential benefits can be gained by cooperation with other traders on the same side of the market, that is, a coalition of importers, or exporters. However, coalitions are difficult to maintain, as members have a constant incentive to 'cheat' to obtain a greater share of the benefits of collusion. Means of deterrence, detection and enforcement are important considerations in cooperative agreements. If such problems can be overcome, significant gains can be made by exploiting the increase in market power that comes with size. This suggests that that Australia might benefit from cooperating with other exporters, such as Canada and Argentina, to force up the world price. Taxes, rather than stocks, would be the most effective policy.

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.

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.

A number of useful refinements could be made to the model presented here. The introduction of stochastic supply and demand disturbances, a multicommodity framework and a longer lag structure could extend the usefulness of the model. Utility functions, with risk preferences, could replace the welfare functions employed here. Ideally, income effects should also be accounted for in the welfare functions. Such refinements are beyond the scope of present research, but may be attempted at a later date.

Perhaps the most interesting extension would involve relaxing the assumption of non-cooperative behaviour. Coalitions of importers or exporters could be analysed, with the possibility of side-payments to discourage cheating on agreements. As a traders could be modelled in a leader-follower (Stackelberg) framework. This may be particularly applicable on the supply side, with the USA as leader. Such models may more accurately reflect the current nature of the international wheat market.

Where international commodity markets are characterised by the used of market power and lags in production or policy responses, dynamic games provide a useful means of analysis. In this paper, 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 in providing more realistic strategic trade models.

References

Bigman, D. (1985), *Food Policies and Food Security Under Instability: Modeling and Analysis*, Lexington Books, Lexington.

Grennes, T., Johnson, P.R. and Thursby, M. (1978), 'Insulating trade policies, inventories and wheat price stability, *American Journal of Agricultural Economics* 60(1), 132-34.

Industries Assistance Commission (1988), 'The Wheat Industry', Report No. 411, AGPS, Canberra.

Karp, L. 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.

Massell, B.F. (1969), 'Price stabilization and welfare', *Quarterly Journal of Economics* 83(2), 284-98.

Newbery, D.M.G. (1984), 'Commodity price stabilization in imperfectly competitive markets', in G.G. Storey, A. Schmitz and A.H. Sarris (eds.) *International Agricultural Trade: Advanced Readings in Price Formation, Market Structure and Price Instability*, Westview Press, Boulder.

Newbery, D.M.G. and Stiglitz, J.E. (1981), *The Theory of Commodity Price Stabilization*, Claredon Press, Oxford.

Nichols, A.L. and Zeckhauser, R.J. (1977) 'Stockpiling strategies and cartel prices', *Bell Journal of Economics* 8(1), 66-96.

Oi, W.Y. (1961), 'The desirability of price instability under perfect competition', *Econometrica* 29(1), 58-64.

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

Scandizzo, P.L., Hazell, P. and Anderson, J.R. (1984), *Risky Agricultural Markets: Price Forecasting and the Need for Intervention Policies*, Westview Press, Boulder.

Shei, S.-Y. and Thompson, R.L. (1977), 'The impact of trade restrictions on price stability in the world wheat market, *American Journal of Agricultural Economics* 59(4), 628-38.

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

Turnovsky, S.J. (1976), 'The distribution of welfare gains from price stabilization: the case of multiplicative disturbance', *International Economic Review* 17(1), 133-148.

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.

—— and —— (1988c), 'Strategic interaction in international commodity markets', Discussion Paper No. 11/88, School of Economics, La Trobe University, Bundoora.

—— and —— (1988d), 'A dynamic game analysis of agricultural trade policy', paper contributed to the Australian Economic Congress, Australian National University, Canberra, 28 August - 2 September.

Vanzetti, D.M. (1988), 'A game-theoretic analysis of agricultural trade policy', paper contributed to the International Economics Postgraduate Research Conference, University of Western Australia, Perth, 6 - 8 November.

Waugh, F.V. (1944), 'Does the consumer benefit from price instability?', *Quarterly Journal of Economics* 58(3), 602-14.

Wright, B.D. and Williams, J.C. (1984), 'The welfare effects of the introduction of storage', *Quarterly Journal of Economics* 98(1), 169-92.

Zwart, A.C. and Meilke, K.D. (1979), 'The influence of domestic pricing policies and buffer stocks on price stability in the world wheat industry', *American Journal of Agricultural Economics* 61(3), 434-47.

Figure 1. Impact of Stockholding