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Nash Equilibrium Tariffs in a Dynamic Stochastic Game: An Application to US and EC Strategic Decisions

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Abstract: Policy making involves dynamics, uncertainty, and strategy, which (although they overlap) can be regarded as separate aspects of the decision maker's problem. Analyzing equilibrium policies (when all considerations are present) and determining how the equilibrium is altered (when one or more aspects is ignored) are made possible by having an analytical tool that nests dynamics, uncertainty, and strategy and permits them to be included in the model in any combination. A tractable dynamic stochastic game (which is such a tool) is discussed, and its merits are indicated by means of an example of strategic tariff and tax policies involving the USA and European Community.

Introduction

When governments of large trading nations choose agricultural policies, at least three aspects of the decision problem must concern them: the time profile of the expected effects of the policies, the riskiness of the policies, and changes in other governments' programmes induced by those policies. The three considerations are intertwined; e.g., the other governments' responses to the policies are uncertain and unlikely to be instantaneous.

Despite lack of a clear distinction, this categorization is useful because it suggests the different analytical tools that can be brought to bear on different aspects of the government's problem. Even in the absence of uncertainty, agricultural markets seldom respond immediately to changed conditions because of the lag between production decisions and harvest and because of a host of other considerations subsumed under "adjustment costs." Because markets do not respond instantaneously, policy analysis requires the use of a dynamic model.

Policy makers' objectives generally involve not only the expected values of quantities (such as producers' incomes, consumer surplus, and programme costs) but also their higher moments. Policy makers are as likely to be risk averse as any other group. Even abstracting from the uncertainty of other governments' responses, the exact effects of a policy cannot be known, which suggests that policy analysis requires a stochastic model.

The third aspect of the decision problem is the most problematical. The welfare effects of a policy depend on the response by trading partners, and selecting the most probable response calls for a large measure of political judgment. Despite this indeterminacy, formal models have a useful role. One approach is to hypothesize a reaction function for foreign countries and use it to simulate the effects of the home country's policies. The most common (but not the most reasonable) hypothesis is that other countries will not respond. Attempts to estimate reaction functions may flounder for lack of data. Even if data are available, the estimation results may not be useful since the reaction functions are probably not invariant to the structure of the world economy, an element of which is the home country's policies. This is essentially the "Lucas critique" of traditional econometrics: a change in the home country's policies will induce changes in the reaction functions and policies of other nations.

An alternative to ignoring or to attempting to estimate reaction functions is to derive them, which requires (as a first step) positing an objective for the foreign country. This alternative clearly does not eliminate the indeterminacy. It merely places it at a more fundamental level, which may be an advantage. Economists are accustomed to specifying objective functions. To perform sensitivity analysis by varying the parameters of these functions is less of a "black box approach" than simply performing sensitivity analysis on the parameters of a reaction function. Policy makers may have some intuition about the relative weights to give to different interest groups in the foreign country; they are less likely to have intuition about the magnitudes of parameters in the reaction function.

A Dynamic Stochastic Game

The introduction of other objective functions transforms the original decision problem into a game. The conclusion of the above discussion is that treating policy making as a dynamic stochastic game is appropriate. A solvable dynamic stochastic game is discussed below, and an example of its usefulness is given. In addition to its tractability, this game has the additional advantage that any of

its features are easily removed, resulting in a simpler model. For example, by choosing the time horizon as one period, a static stochastic game is obtained; by removing all but one player, a stochastic control problem is obtained. The analyst can, therefore, determine how the three aspects of the basic problem jointly influence the result and gauge the individual contribution of each aspect. How does consideration of uncertainty or strategy alter policy recommendations?

The determination of import tariff and export tax policies in large countries provides an example of this issue. Finding the optimal tariff/tax in the deterministic static case is equivalent to solving the standard monopoly/monopsony problem (Enke, 1944). Thursby and Jensen (1983) studied the role of conjectural variations in a deterministic static game involving tariffs and two players. Tower (1975) considered a repeated game involving tariffs and quotas. Helpman and Razin (1978) studied the effect of uncertainty on optimal tariffs. Karp and McCalla (1983) calculated optimal tariffs/taxes in a deterministic dynamic game. Paarlberg and Abbott (1981) and Sarris and Freebairn (1983) estimated the weights that different countries attach to the welfare of different groups in setting tariff/tax equivalents. This brief review suggests some of the interest in the effect of market structure on tariff levels. But this author is not aware of any numerical or analytical studies dealing simultaneously with dynamics, uncertainty, and strategy (games).

The attention given to tariffs/taxes in international policy research is understandable, but tariff/tax policies do not constitute the most important impediments to trade. Nontariff barriers (such as variable levies, deficiency payments, and voluntary quotas) probably play a larger role in international trade (Hillman, 1978). The concern with tariffs is (in part) justified by the argument that other policies can be expressed as tariff equivalents. This has to be interpreted carefully, since, for both games and stochastic problems, the form of admissible control rules affects the solution. Not only do tariffs and quotas generally lead to different results but so do specific and *ad valorem* tariffs. With this caveat in mind, we turn to a discussion of the dynamic stochastic game and its application to the analysis of equilibrium tariffs.

Consider a group of m traded commodities with world price in period t given by the vector p_t . Country i chooses a vector of tariffs/taxes in period t , u_{it} , $i = 1, 2 \dots n$, so domestic price in country i in period t is $p_t + u_{it}$. Define $u_t = (u'_{1t} \dots u'_{nt})'$. The evolution of world price is approximated by the difference equation:

$$(1) \quad p_t = L(p_{t-1}, u_t, u_{t-1}, v_t),$$

where $L(\cdot)$ is linear in its arguments, and v_t is normally distributed with mean and variance v_p, Σ_p . System (1) can be estimated or constructed by setting the sum of excess demand of the n countries equal to zero. The system is dynamic because not all adjustment occurs in one period.

The single period payoff to country i in period t is approximated by $Q_{it}(p_t, p_{t-1}, u_t, u_{t-1})$, where Q_{it} is linear-quadratic in its arguments; Q_{it} may be a weighted sum of producer and consumer surplus and tariff/tax revenue or it may give the squared deviation of actual values of p and u from target values. Define $Q_i \equiv \sum \beta_i^t Q_{it}(\cdot)$, which is the discounted sum of the payoff to country i over T years with discount rate β_i . Define $\pi_i \equiv -\exp - k_i Q_i$, $k_i > 0$, where π is the utility that country i obtains from Q_i assuming a constant absolute risk aversion utility function with risk parameter k_i . Country i 's objective is to maximize the expectation of π_i , subject to equation (1) and the behaviour of the $n-1$ other countries.

The two most plausible solution concepts are Stackelberg and noncooperative Nash. The former assigns to one country or group of countries a leadership role; the other countries take the leader's policies as given. The Nash solution, which is used below, treats all countries symmetrically; each takes the policies of its rivals as given. Notice that they do not take the actual tariffs or taxes as given but only the policies by which those tariffs or taxes are determined. The policies, or control rules, are of the form $u_{it} = L_{it}(p_{t-1}, u_{t-1})$, where L_{it} is a linear function. The algorithm for the Nash equilibrium rules is given in Karp (1984b). The parameters of L_{it} are complicated functions of the parameters of equation (1), the moments of the random vector v_t , the parameters of all payoff functions, and all risks aversion parameters. As the variance (Σ) goes to zero (or all risk aversion parameters go to zero), the game collapses to the linear-quadratic dynamic game solved by Kydland (1975); with only one player, the game collapses to the linear exponential Gaussian control problem solved by Jacobson (1973).

The usefulness of the model is illustrated by the following two questions:

- In a one-player game (a control problem), how does the degree of risk aversion affect the expected level of the tariff and the stability of world price?
- With two or more players, how are equilibrium strategies affected by changes in one player's aversion to risk?

The first question concerns the sensitivity of the optimal dynamic tariff in a stochastic setting. The second question arises when one wants to know whether making one player more risk averse causes that player's opponent to behave either more or less cautiously.

Answering these questions for general values of the parameters of equation (1) and π_i is impossible due to the complexity of the solution of the dynamic stochastic game. A model of the world maize market (used by Karp and McCalla, 1983) involves reasonable parameter values and was used for sensitivity studies (a random term was added to their price equation). That model was constructed by using estimated elasticities to generate regional supply and demand equations, which were then equated to obtain equation (1). Country i 's single period payoff (Q_{it}) was taken to be the sum of producer and consumer surplus and tariff/tax revenues.

To answer the first question, the European Community (EC) was assumed to have solved a controlled problem; i.e., other nations' policies did not respond to EC policies. The conclusion is that as the EC becomes more risk averse, its equilibrium policy is changed in such a way as to increase the stability of both world price and its specific tariff and, consequently, of its domestic price. This results in a lower average tariff, a higher average world price, a smaller expected payoff (Q_i), and a smaller variance of the payoff. A more detailed discussion of these results is found in Karp (1984a). In a static model, a country can completely stabilize domestic price by increasing the instability of world price. In a dynamic model, that is not optimal because that policy amplifies the instability of tariff revenues (e.g., suppose an unusually large harvest caused domestic price to fall for a given tariff). Increasing the tariff stabilizes the domestic price at the usual level and transfers the instability abroad in the form of a lower world price. If producers have adaptive expectations (as was assumed in this experiment), foreign production is discouraged, which causes world price to be unusually high in the next period. In order to hold the domestic price at the usual level, an unusually low tariff is required in that period. In both the static and dynamic models, domestic price stability is bought at the cost of tariff revenue instability, but, in the dynamic model, the effect of that instability is felt in subsequent periods as well as in the current one. Therefore, the tariff-imposing country has an interest in international price stability, and this interest increases as its risk aversion increases, inducing it to lower its tariffs.

To answer the second question, a game between the EC and the USA was studied. The objective was to determine how an increase in one country's risk aversion affects the equilibrium policies of the second country. The following results hold over a range where both countries are risk averse and where sufficiency conditions for the game are satisfied. The USA (an exporter) imposes a tax. As either country is made more risk averse, its own trade intervention decreases. The explanation is the same as given above. As the EC is made more risk averse (holding US risk aversion constant), the expected US tax increases. But as the USA is made more risk averse (holding EC risk aversion constant), the expected EC tariff decreases; i.e., as increased caution in the USA causes it to reduce trade barriers, the EC follows suit, but as the EC's increased caution causes it to reduce trade barriers, the USA responds by increasing its expected tax. This asymmetry does not have an obvious interpretation. The probable cause is that (in this model) the US tax has a much larger impact on the world price than the EC tariff, meaning that, although the two players are engaged in a Nash game, the USA is in some sense dominant.

Since an increase in the EC risk aversion causes the EC tariffs to fall and the US tax to rise, an unambiguous increase occurs in expected world price. The increase in US tax aversion causes a decrease in US tax and a decrease in EC tariff. These changes influence the world price in the opposite direction (both excess supply and demand shift out). The net effect is to decrease expected world price.

The expected payoff (Q_i) of a country increases as its rival becomes more risk averse, and the variance of its payoff decreases. This has an obvious explanation: in general, facing a cautious rival is better.

Conclusions

These results derive from a specific model, so no claim for generality is made. They are not intended to provide a basis for advising policy makers, rather to demonstrate the usefulness of an analytical tool that has not previously been employed. International policy making is not really a noncooperative Nash game. However, that description seems at least as plausible as characterizing policy decisions as an optimization problem. The advantage of the game discussed here is that it nests the dynamic, uncertain, and strategic elements of the decision problem. Any element can be removed from the model, resulting in a simpler problem. This makes the technique particularly suited to policy simulation studies.

Note

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