DUSTRIAL ORGANIZATION AND INTERNATIONAL TRADE: HODOLOGICAL FOUNDATIONS FOR INTERNATIONAL FOOD AND AGRICULTURAL MARKET RESEARCH

Organization
and Performance
of World Food
Systems: NC-194

Ian M. Sheldon and Dennis R. Henderson, editors

North Central Regional Research Publication Number 334

NC-194 Research Monograph Number 1

July 1992

Agricultural Experiment Stations of California, Connecticut, Florida, Illinois, Indiana, Iowa, Kentucky, Louisiana, Maryland, Michigan, Minnesota, Mississippi, Missouri, Nebraska, New York, North Dakota, Ohio, Oklahoma, Oregon, Texas, Virginia, Washington, and Wisconsin, and the U.S. Department of Agriculture, cooperating.

United States Department of Agriculture

National Agricultural Library

Spons
Unive
Unive
Corne

University of Florida	James Seale, Ronald Ward
University of Illinois	Gerald Nelson, Lowell Hill
Iowa State University	William Meyers, Marvin Hayenga
Kansas State University	Brooke Wilson, Marc Johnson
University of Kentucky	Michael Reed, Loys Mather
Louisiana State University	
University of Maryland	Earl Brown
Michigan State University	James Shaffer
University of Minnesota	Harald von Witzke
Mississippi State University	Ying-Nan Lin
University of Missouri	Maury Bredahl, Michael Cook, Kenneth Schneeberger
University of Nebraska	Wesley Peterson, Azzeddine Azzam, Nancy Cottrell
North Dakota State University	Won Koo
Ohio State University	Dennis Henderson, Ian Sheldon, James Dayton, Thomas Sporleder, Joseph Hirschberg
Oklahoma State University	Shida Henneberry
Oregon State University	Patricia Lindsey
Purdue University (Indiana)	John Connor, Thomas Hertel, Philip Abbott, Lee Schrader, James Binkley, Marie Thursby
Texas A&M University	Gary Williams, John Nichols, Alan Love
Virginia Polytechnic Inst. & SU	Eluned Jones
Washington State University	Thomas Wahl
University of Wisconsin	Bruce Marion, Jay Coggins
U.S. Department of Agriculture	
Agricultural Coop. Serv.	James Haskell, Stuart Frank, Bruce Reynolds
Agricultural Marketing Serv.	Larry Summers, Ken Clayton
Cooperative State Res. Serv.	Roland Robinson, Paul Farris
Economic Research Serv.	Lester Myers, John Dunmore, Charles Handy, Michael Ollinger, David Kelch, Bradley McDonald, Jerry Sharples, Lee Christensen
Extension Service	David Holder
Farm Foundation	Walter Armbruster

Administrative Advisor = Kenneth Schneeberger; Executive Director = Dennis R. Henderson; Administrative Assistant = Carol A. Russell

Proceedings of a Workshop On Industrial Organization and International Trade

Editors:
Ian M. Sheldon
Dennis R. Henderson

Published at The Ohio State University
Columbus, Ohio 43210-1099

Chapter 4: Imperfect Competition and International Trade: The Use of Simulation Techniques

Ian M. Sheldon

4.1 Introduction

Following the publication of Brander and Spencer's (1985) paper, there has been considerable development in the literature concerning the use of industrial and trade policy where markets are imperfectly competitive.[1] Much of this literature indicates that, given divergences between price and marginal cost, it may be optimal for governments to help domestic firms capture a larger share of rents from international markets through the use of policies such as export subsidies and import tariffs. Examples of the analysis of "strategic" trade policy in the agricultural economics literature are Thursby (1988), who applies the Brander and Spencer rationale to trade in wheat, and McCorriston and Sheldon (1991), who apply Dixit's (1988a) model to the UK fertilizer market, taking into account the effect on optimal trade policies of changes in market structure.

Despite these theoretical developments, very little empirical work has been conducted to test the scope and significance of the theoretical results. The research that has been done focusses entirely on the use of simulation techniques, the best-known industry-level studies being those of Dixit (1988b), Baldwin and Krugman (1988), Dixit (1988b), and Venables and Smith (1986, 1988). There have also been some general equilibrium studies, notably that of Cox and Harris (1985).[2]

These simulation methods, which are conducted in a manner very similar to computable general equilibrium models, have been labelled by Krugman (1986) as, "Industrial Policy Exercises Calibrated to Actual Cases" (IPECACs). The basic method is to specify a theoretical model that captures certain features of imperfectly competitive markets such as oligopolistic interaction, product differentiation and scale economies. Each model contains a number of parameters and endogenous variables such as prices and quantities.

---

[1] For a recent survey of this literature, see Helpman and Krugman (1989).

[2] See Norman (1989) and Richardson (1990) for useful surveys of this literature.

Some of the parameters are taken from external estimates; the rest are calibrated to the model to copy the chosen base-period data. The models are used to simulate changes in policy, such as the imposition of import tariffs, and the relevant welfare effects are calculated.

The objective of this paper is to provide both an understanding of the workings of such models, how to use them and also their limitations. As this is a relatively new area of research, there is no generally accepted methodology apart from the basic process of calibration; thus, focussing on some specific calibration/simulation models is a means of understanding the procedure and its limitations. Section 2 examines in some detail the types of theoretical models that have been developed and the process of model calibration. In order to keep the analysis manageable, only industry-level, partial equilibrium models are considered. Section 3 considers the types of problems such techniques have been used to address, while in Section 4, the limitations of the technique are outlined.

4.2 Calibration/Simulation Models

While several theoretical models have been developed in the calibration/simulation literature, in keeping with Helpman and Krugman (1989), I divide them into two types. First, there are those models that assume a fixed market structure, irrespective of changes in government policy. The focus here will be on the pioneering work of Dixit (1988b) and Thursby and Thursby (1990, 1991). These two models also provide a useful contrast in approaches to model calibration. The second group of models assume there is freedom of entry and exit, such that, in equilibrium, profits are driven to zero.[3] The models formed by Baldwin and Krugman (1988) and Venables and Smith (1986, 1988) will be considered here. These two models are also of interest in the manner in which they deal with economies of scale.

The distinction between market structures is useful for two reasons. First, the models with fixed firm numbers allow for a direct test of the Brander and Spencer "rent-shifting" argument for trade policies, as firms will be making profits in the base-line equilibrium. In contrast, the free-entry models focus on the gains from policy where firms are able to more fully realize economies of scale and consumers benefit from greater variety as new firms enter into differentiated

[3] If an integer constraint is observed, there can be positive profits in equilibrium that would disappear with further entry.

markets. Second, free-entry models imply that in equilibrium, prices will equal average costs; consequently, where cost data is unavailable, inferences can be made about costs from the observed market outcome.

4.2.1 Models with Fixed Market Structure

The earliest example of an IPECAC is that developed by Dixit (1988b), which he applied to the U.S. automobile industry. The model, based on Dixit's (1988a) theoretical work, has a relatively simple structure and is fairly "user-friendly". The model is set up in the context of a market structure where a number of symmetric, domestic firms (subscript 1) compete in the home market with a number of symmetric, foreign firms (subscript 2). Both sets of firms are assumed to face a constant cost technology, market structure is fixed, and although the domestically produced product is homogeneous, as is the foreign product, the two product types need not be perfect substitutes.

If other sectors of the economy are regarded as a competitive *numeraire*, so that the consumer's utility function is linear and separable in the *numeraire*, partial equilibrium analysis can be conducted with respect to the two goods. A representative consumer maximizes surplus as given by:

$$S_i = U(Q_1,Q_2) - \sum_{i=1}^{2} p_i Q_i \qquad 4.1$$

where Q_i and p_i are the amount and price of the home and foreign good respectively, and the utility function $U(Q_1,Q_2)$ is the following:

$$U(Q_1,Q_2) = a_1 Q_1 + a_2 Q_2 - (b_1 Q_1^2 + b_2 Q_2^2 + 2kQ_1Q_2)/2 \qquad 4.2$$

where a_i, b_i and k are assumed positive.

This utility maximizing problem generates the following inverse demand functions:

$$p_1 = a_1 - b_1 Q_1 - kQ_2 \qquad 4.3$$

$$p_2 = a_2 - b_2 Q_2 - kQ_1 \qquad 4.4$$

where $b_1b_2-k^2>0$ if the products are imperfect substitutes, $b_1b_2-k^2=0$ if they are perfectly substitutable. The direct demand functions can be written as:

$$Q_1 = A_1 - B_1 p_1 + K p_2 \qquad 4.5$$

$$Q_2 = A_2 - B_2 p_2 + K p_1 \qquad 4.6$$

where all the parameters are positive and as above, the same conditions on B_1B_2-K^2 apply. The parameters of the inverse demand system can also be expressed in terms of the direct demand system as:

$$a_1 = \frac{A_1 B_2 + K A_2}{B_1 B_2 - K^2}; \qquad a_2 = \frac{A_2 B_1 + K A_1}{B_1 B_2 - K^2}$$

$$b_1 = \frac{B_2}{B_1 B_2 - K^2}; \qquad b_2 = \frac{B_1}{B_1 B_2 - K^2}; \qquad k = \frac{K}{B_1 B_2 - K^2} \qquad 4.7$$

On the supply side, there are n_1 and n_2 domestic and foreign firms respectively. Profits for a representative firm in each sector are given by:

$$\pi_1 = (p_1 - c_1 + s) q_1 \qquad 4.8$$

$$\pi_2 = (p_2 - c_2 - t) q_2 \qquad 4.9$$

where c_i are costs, s is a production subsidy that may be paid to the domestic firm, and t is a tariff that may be imposed on the imported product.[4]

The behavioral assumption of the model is one where firms' reactions to one another are treated as a Nash equilibrium with conjectural variations. (The problems associated with this approach to modelling oligopoly are discussed in Section 4.4). Following Dixit (1988a), suppose the conjectures are denoted as v_{ij}, where i,j=1,2, and are interpreted as the amount by which each firm i believes each other firm j will respond to a variation in its output. Hence a domestic firm

[4] Dixit (1988a) has shown that in a full optimum, a production subsidy should be targeted at the domestic firms in order to remove the monopoly distortion and a tariff imposed on imports.

expects domestic output Q_1 to increase by $1+(n_1-1)v_{11}$ when it increases its output by one unit and imports Q_2 to increase by n_2v_{12}.

Assuming domestic and foreign firms set output to maximize profits, the first-order conditions can be written as:

$$p_1 - c_1 + s + q_1[\frac{\delta p_1}{\delta q_1}\{1 + (n_1 - 1)v_{11}\} + \frac{\delta p_1}{\delta q_2}n_2v_{12}] \qquad 4.10$$

$$p_2 - c_2 - t + q_2[\frac{\delta p_2}{\delta q_2}\{1 + (n_2 - 1)v_{22}\} + \frac{\delta p_2}{\delta q_1}n_1v_{21}] \qquad 4.11$$

Given the n_1 domestic and n_2 foreign firms are assumed to be symmetric, expressions (4.10) and (4.11) can be aggregated to give:

$$p_1 - c_1 + s - Q_1V_1 = 0 \qquad 4.12$$

$$p_2 - c_2 - t - Q_2V_2 = 0 \qquad 4.13$$

where the aggregate versions of the conjectural variations parameters can be defined as:

$$V_1 = [b_1\{1 + (n_1 - 1)v_{11}\} + kn_2v_{12}]/n_1 \qquad 4.14$$

$$V_2 = [b_2\{1 + (n_2 - 1)v_{22}\} + kn_1v_{21}]/n_2 \qquad 4.15$$

The conjectural variations parameters V_i can reflect varying degrees of competitiveness in the market. For example, if firms act in Cournot fashion, $V_i = -b_i/n_i$, and as n_i increases, the more competitive the Cournot outcome becomes. In the limit, $V_i=0$, i.e., the perfectly competitive outcome.

Notice that although conjectures can be split into components corresponding to the separate responses of the domestic and foreign firms, these are collapsed into the single parameter V_i, which determines the effect of domestic and foreign firms' behavior on the market outcome. Consequently, in calibrating Dixit's (1988b) model, given data on p_i, Q_i, c_i, t and s, the V_i can be solved for from the first-order conditions (4.12) and (4.13). However, as will be discussed shortly, Thursby and Thursby (1990) explicitly separate out the conjectures in their work.

In order to obtain equilibrium prices and quantities following a change in the policy regime, the first-order conditions (4.12) and (4.13) are combined with the inverse demand functions, the explicit solutions being:

$$\begin{bmatrix} Q_1 \\ Q_2 \end{bmatrix} = \frac{1}{\Delta'} \begin{bmatrix} b_2 + V_2 & -k \\ -k & b_1 + V_1 \end{bmatrix} \begin{bmatrix} a_1 - c_1 + s \\ a_2 - c_2 - t \end{bmatrix} \qquad 4.16$$

$$\begin{bmatrix} p_1 \\ p_2 \end{bmatrix} = \begin{bmatrix} a_1 \\ a_2 \end{bmatrix} - \frac{1}{\Delta'} \begin{bmatrix} \Delta + b_1 V_2 & k V_1 \\ k V_2 & \Delta + b_2 V_1 \end{bmatrix} \begin{bmatrix} a_1 - c_1 + s \\ a_2 - c_2 - t \end{bmatrix} \qquad 4.17$$

where $\Delta=(b_1b_2-k^2)$ and $\Delta'=(b_1+V_1)(b_2+V_2)-k^2$.

Turning to Thursby and Thursby's (1990) model, this is essentially of the same generic type as Dixit's (1988b), the major difference being the context in which it is used and the manner in which conjectural variations are handled. Following the Brander and Spencer model, Thursby and Thursby (1990) consider a situation where two countries, both producing an agricultural commodity, compete in the world market. The commodity is produced under competitive market conditions in each country, and sales are conducted through distributors in both the home and world market. In country 1, distribution is via a marketing board, while in country 2, distribution is via n private firms, j=1....n, each assumed to maximize profits. Of these firms, g sell in the domestic and export market, h sell only in the domestic market. Similar to Dixit's (1988b) model, the two countries' commodities are not necessarily perfect substitutes.

The model is based on the same type of demand system described in expressions (4.3)-(4.6) for the world market, where in what follows, p_i^x and Q_i^x are the prices and quantities of commodity exports from the two countries, subscript 1 referring to the marketing board in country 1, subscript 2 to the private marketing firms in country 2. The superscript x refers to exports, and p_i^x can incorporate tariffs. An inverse demand function for the commodity also exists in each country where p_i^d and Q_i^d are the respective domestic prices and quantities.

For simplicity, assume the world market is one country. The marketing board maximizes the joint returns R_1 of domestic commodity producers plus export revenue, while the private marketing firms in country 2 maximize profits, their respective objective functions being:

$$R_1 = (p_1^d + r_1)Q_1^d + (p_1^x - c_1^x + xs_1)Q_1^x - f_1 - \int_0^{Q_1^d + Q_1^x} [p_1^f(q) - s_1]dq \qquad 4.18$$

$$\begin{aligned}\pi_{2j} = {} & p_2^d q_{2j}^d + p_2^x q_{2j}^x - p_2^f(Q_2^d + Q_2^x)(q_{2j}^d + q_{2j}^x) \\ & - f_{2j}^x - f_{2j}^d + (s_2 + r_2)q_{2j}^d + (s_2 + xs_2 - c_2^x)q_{2j}^x\end{aligned} \qquad 4.19$$

In expression (4.18) for the marketing board p_1^d, p_1^x, Q_1^d, Q_1^x are as defined, $p_1^f(q)$ is the competitive commodity supply price, c_1^x are export transport costs, f_1 are fixed costs and r_1, xs_1 and s_1 are consumer, export and marketing board subsidies respectively.[5] Expression (4.19) refers to that for a representative firm j, where p_2^d, p_2^x, q_{2j}^d and q_{2j}^x are as defined and $p_2^f(Q_2^d+Q_2^x)$ is the competitive commodity supply price, c_2^x are export transport costs, f_{2j}^x and f_{2j}^d are the fixed costs of export and domestic operations, where for firms j=1....g, f_{2j}^x are lower than those for firms j=g+1....n, i.e., export firms g have an advantage over those that compete only in the domestic market. Finally, r_2, xs_2 and s_2 are consumer, export and producer subsidies respectively.

As with Dixit's (1988b) model, the behavioral assumption adopted here is one of a Nash equilibrium with conjectural variations. So assuming the marketing board is not regulated in country 1,[6] its first-order conditions in the home and export market are:

$$p_1^d(1 + e_1^d) = p_1^f - (s_1 + r_1) \qquad 4.20$$

$$p_1^x(1 + e_1^x + e_{12}^x v_{12} Q_1^x/Q_2^x) = p_1^f + c_1^x - (s_1 + xs_1) \qquad 4.21$$

where e_1^d is the domestic inverse elasticity of demand, e_1^x is the inverse elasticity of demand for country 1's exports, and e_{12}^x is the inverse cross elasticity of demand for country 1's exports with respect to

---

[5] These policies are included in line with Thursby's (1988) earlier analysis of optimal intervention whereby policies are targeted at each distortion, i.e. the consumer subsidy deals with monopoly power, the marketing board subsidy with any potential monopsony power and the export subsidy with foreign trade.

[6] The case of a regulated marketing board is also considered by Thursby and Thursby.

country 2's exports. v_{12} is the marketing board's conjecture about how country 2's firms will react to a change in its output, i.e., dQ_2^x/dQ_1^x, where for Cournot conjectures $v_{12}=0$. In the case of Bertrand conjectures, the marketing board believes that when it increases its exports, country 2's firms will reduce their exports by just enough to keep their prices constant. Hence the conjectural variations term v_{12} can be defined as:[7]

$$v_{12} = \left(\frac{\delta Q_2^x}{\delta p_1^x} \Big/ \frac{\delta Q_1^x}{\delta p_1^x} \right) \Bigg|_{\delta p_2^x = 0} = \frac{K}{-B_1} = -\frac{k}{b_2} \qquad 4.22$$

where K, B_1, k and b_2 are taken from the direct and inverse demand functions respectively. If the goods are perfect substitutes, $v_{12}=-1$ which would be the limiting case of perfect competition, and as the goods become less substitutable, v_{12} declines in value.

For the private firms in country 2, it is assumed that the domestic market is competitive, the focus being on the first-order condition for those firms that export. As with Dixit (1988b), there are g symmetric exporters, the first-order condition for a representative firm being:

$$\begin{aligned} p_2^x[1 + (e_2^x/g)(1 + v_{j22}) + e_{21}^x v_{j21} q_{2j}^x/Q_1^x] \\ = p_2^f + c_2^x - s_2 - x s_2 + \psi q_{2j}^x(1 + v_{j22}) \end{aligned} \qquad 4.23$$

where e_2^x is the inverse elasticity of demand for country 2's exports, e_{21}^x is the inverse cross elasticity of demand for country 2's exports with respect to country 1's exports. v_{j22} is the conjecture of a representative exporting firm about other exporting firms from country 2, while v_{j21} is the conjectural variations term vis-à-vis the marketing board.[8] Ψ is defined as $\delta p_2^f/\delta(Q_2^d+Q_2^x)$. Again the conjectural variations terms take particular values for the Cournot and Bertrand cases. Critically, however, it is possible that $v_{j22} \neq v_{j21}$.

In order to obtain equilibrium prices and quantities following

---

[7] See Eaton and Grossman (1985) for a derivation of this.

[8] Note that v_{j21} is defined in a similar fashion to v_{j12} and can be derived in similar fashion, however, v_{j22} cannot be derived explicitly in terms of the parameters of the demand system.

a change in policy, the first-order conditions (4.20) and (4.21), g versions of (4.23), a market-clearing equation for country 2's domestic market, and the inverse demand functions for exports are combined in order to get a solution similar to (4.16) and (4.17).

4.2.2 Calibration of Models with Fixed Market Structure

Turning to the process of calibrating the two models outlined, although they are essentially the same model, differing approaches to calibration have been adopted. In the case of Dixit's (1988b) model, if the focus is on equations (4.3)-(4.6), in order to use the model for simulation, estimates of the demand parameters are required. Inspection of (4.5) and (4.6) shows that, given base-line values of P_1, P_2, Q_1 and Q_2, there are still five unknowns, A_1, A_2, B_1, B_2 and K; consequently, three further expressions are required to solve the system. Dixit (1988b) deals with this by deriving expressions for the elasticities of demand and substitution which can then be set equal to external estimates of those parameters.

Taking the price elasticity of demand first, as the products are being treated as imperfect substitutes, this is interpreted as being the effect of an equiproportionate rise in the price of the two products on total consumer expenditure Q. Therefore letting $p_1=p_1^0P$ and $p_2=p_2^0P$, where p_1^0 and p_2^0 are initial prices and P is the proportional change factor, consumer expenditure can be written as:

$$Q = p_1^0 Q_1 + p_2^0 Q_2 \qquad 4.24$$

Given that in calibrating the model, p_1 and p_2 will be the initial base-line prices, and given (4.5) and (4.6), then (4.24) can be re-written as:

$$Q = p_1 A_1 + p_2 A_2 - (B_1 p_1^2 + B_2 P_2^2 - 2Kp_1 p_2)P \qquad 4.25$$

The total market elasticity of demand for the product, ε, is then defined and evaluated at the base-line point where P equals 1. By differentiating (4.25) with respect to P, and multiplying by P/Q, the elasticity is given by:

$$\varepsilon = \frac{-(B_1 p_1^2 + B_2 p_2^2 - 2Kp_1 p_2)}{Q} \qquad 4.26$$

which is then set equal to the external estimate of ε.

The elasticity of substitution would normally be defined as:

$$\sigma = d\log(Q_1/Q_2)/d\log(p_1/p_2) \qquad \textbf{4.27}$$

which gives a fourth expression when set equal to an external estimate of σ. However, (4.5) and (4.6), in general, define the ratio Q_1/Q_2 as a function of the vector (p_1,p_2) and not in terms of p_1/p_2. For Q_1/Q_2 to be a function of p_1/p_2, at least locally, the parameters are assumed to satisfy the following fifth expression:

$$p_1(A_1K + A_2B_1) = p_2(A_2K + A_1B_2) \qquad \textbf{4.28}$$

which implies homotheticity of the utility function.

From (4.27), and using (4.5),(4.6) and (4.28), the final expression for σ is:

$$\sigma = \frac{\frac{p_1}{p_2}(B_1B_2 - K^2)}{(B_1\frac{p_1}{p_2} - K)(B_2 - K\frac{p_1}{p_2})} \qquad \textbf{4.29}$$

Given base-line values of p_1, p_2, Q_1 and Q_2, and external estimates of ε and σ, estimates of the direct demand parameters A_1, A_2, B_1, B_2 and K are obtained by solving the simultaneous equation system (4.5), (4.6), (4.26), (4.28) and (4.29). In turn (4.7) is used to obtain estimates of the inverse demand parameters a_1, a_2, b_1, b_2 and k. Finally, in order to run simulations and solve (4.16) and (4.17), estimates of the aggregate conjectural variations parameters V_1 and V_2 are required. As noted earlier, these are obtained by using base-line data on p_i, Q_i, s and t, estimates of c_i, and expressions (4.12) and (4.13). Note that Dixit (1988b) assumes that marginal costs can be approximated by average variable costs in his analysis.

It turns out that interpreting the V_i directly is not easy; as a result, Dixit (1988b) has suggested the following procedure. Given the derived values of V_i, if these actually reflected Cournot behavior, then the Cournot-equivalent number of firms would be $n_i^c = b_i/V_i$; this can then be compared with the actual number of firms n_i, where n_i is based on the numbers-equivalent of the Herfindahl index. Using the latter is necessary given the assumption of symmetric firms. Given n_i^c and n_i, the following applies:

$n_i < n_i^c$ - the market is more competitive than Cournot
$n_i = n_i^c$ - the market exhibits Cournot behavior
$n_i > n_i^c$ - the market is less competitive than Cournot

As an example of this type of calculation, for 1980, Dixit (1988b) derived a value of V_1 for U.S. automobile firms of 4.66494^{-5}, which implied a Cournot-equivalent number of firms of 19.116. This compared with the numbers-equivalent of the Herfindahl index of 2.077, i.e., the conduct of U.S. firms was a lot more competitive than the Cournot outcome in that year.

This is clearly a very crude test of market competitiveness, and because the model is only calibrated to one base-period, no variances can be attached to the values of V_i. This problem is dealt with explicitly in the calibration method adopted by Thursby and Thursby (1990). They assume that exporters in both countries ignore any effects on domestic commodity supply prices, so the focus is on estimating the conjectural variations parameters v_{12}, v_{j22} and v_{j21}. Explicit expressions for these can be obtained by re-arranging the first-order conditions. For the marketing board, re-arranging (4.21):

$$v_{12} = -Q_2^x(\mu_1 + p_1^x e_1^x)/e_{12}^x p_1^x Q_1^x \qquad 4.30$$

$$where \quad \mu_1 = (p_1^x - p_1^f - c_1^x + xs_1 + s_1)$$

In any given year, base-line data are available for p_1^x, Q_1^x, Q_2^x and μ_1, but the inverse demand elasticities e_1^x and e_{12}^x are not observable. Rather than follow the Dixit (1988b) approach, Thursby and Thursby (1990) choose to estimate the elasticities and then solve for the conjectural variations term.

For the g exporters in country 2, expression (4.23) indicates that an explicit expression for either of the conjectural variations terms would have to be conditioned on an assumed value for the other, i.e., in solving for v_{j21}, v_{j22} would be assigned a value, and vice-versa. So rearranging (4.23) and summing over the g exporting firms:

$$v_{j21} = -Q_1^x[g\mu_2 + p_2^x e_2^x(1 + v_{j22})]/e_{21}^x p_2^x Q_2^x \qquad 4.31$$

$$v_{j22} = -[g\mu_2 + p_2^x(e_2^x + e_{21}^x v_{j21} Q_2^x/Q_1^x)]/p_2^x e_2^x \qquad 4.32$$

$$where \quad \mu_2 = (p_2^x - p_2^f - c_2^x + xs_2 + s_2)$$

In any given year, p_2^x, Q_1^x, Q_2^x and μ_2 are available, and as with Dixit's (1988b) model, the numbers-equivalent of the Herfindahl index is used to derive g due to the assumed symmetry of firms. For example, in the years that Thursby and Thursby (1990, 1991) looked at U.S. wheat exporting firms, there were 30 to 60 firms in the market, with Herfindahl indices ranging from 0.07 to 0.11, which in numbers-equivalent form implied symmetric firm numbers in the range 9 to 14. The remaining elasticities are then estimated econometrically. In order to obtain estimates of the inverse demand elasticities, Thursby and Thursby (1990, 1991) estimate linear inverse demand functions of a form similar to (4.3) and (4.4) using time-series data.

In contrast to Dixit's (1988b) methodology, because Thursby and Thursby (1990, 1991) have estimated variances of the inverse demand elasticities, they are able to approximate variances for the estimated conjectural variations parameters, and so are able to conduct statistical tests as to whether conjectures are significantly different from zero, the Cournot case. These conjectures were estimated for the Canadian Wheat Board and private U.S. exporting firms over the period 1976/77 to 1984/85. An example of their results for 1984/85 are:

$$v_{12} = \underset{(0.672)}{-1.223}$$

v_{j21} given	v_{j22}	v_{j22} given	v_{j21}
-0.160 (0.067)	-0.900 (B)	-0.546 (0.188)	-0.810 (B)
-0.895 (0.382)	-0.500	-0.715 (0.116)	-0.500
-1.814 (0.777)	0.000 (C)	-0.987 (0.003)	0.000 (C)

Source: Thursby and Thursby (1991) B = Bertrand
(Standard errors in parentheses) C = Cournot

The conditional value of v_{j22} is set at 0 for the case of Cournot, and -0.9 for the case of Bertrand, just below the limiting case of perfect competition, and the value of -0.5 represents the case of competition somewhere between Cournot and Bertrand competition with homogeneous goods. The conditional value of v_{j21} is set at 0 for Cournot behavior and -0.5 for more competitive behavior, while the case of Bertrand behavior is derived from the estimates of the own price and cross-price parameters k and b_1. These results indicate that the estimated conjectures of both the Canadian Wheat Board and private U.S. firms were significantly different from Cournot behavior, i.e., firms were behaving more competitively. Similar results were found for the other marketing years in the sample.

4.2.3 Models with Free Entry/Exit

The best-known examples of IPECACs with free entry/exit assumptions are those of Baldwin and Krugman and Venables and Smith. Compared to the fixed market structure models of the previous section, these models are quite different in structure, their main similarity is that they both incorporate economies of scale and draw on theoretical models from the intra-industry trade literature.

The distinctive feature of Baldwin and Krugman's model, is the modelling of learning economies, which under certain circumstances are a form of increasing returns. Suppose at the start of a product cycle a firm j invests in capacity K_j which can be used to produce one "batch" per unit of time t. Over the cycle, because of learning, it is assumed that the yield of any batch increases according to:

$$y_j(t) = [K_j\ t]^{\theta} \qquad 4.33$$

Hence total output q_j in any time period will be:

$$q_j(t) = K_j y_j(t) = K_j^{1+\theta} t^{\theta} \qquad 4.34$$

and cumulative output to date is found by integrating (33):

$$\int_0^t (K_j^{1+\theta} t^{\theta}) dt = \chi_j(t) = \frac{(K_j t)^{1+\theta}}{(1+\theta)} \qquad 4.35$$

Assuming the cost of a unit of capacity can be annualized, then current average costs $C_j(t)$ are:

$$C_j(t) = \frac{c_j K_j}{q_j(t)} = c_j(K_j t)^{-\theta} \qquad 4.36$$

where c_j is the annualized cost of a unit of capacity. Rearranging (34) in terms of ($K_j t$) and substituting into (4.36), an expression for the behavior of costs over time is:

$$C_j(t) = c_j[\chi_j(t)(1 + \theta)]^{-\theta/(1+\theta)} \qquad 4.37$$

where $\theta/(1+\theta)$ can be interpreted as the slope of the learning curve.

Given this technology, Baldwin and Krugman describe a market structure very similar to the "reciprocal" dumping models of intra-industry trade of Brander (1981) and Brander and Krugman (1983). There are two countries, 1 and 2, where the relevant demand functions are of constant elasticity form:

$$p_1 = a_1 Q_1^{-\varepsilon} \qquad 4.38$$

$$p_2 = a_2 Q_2^{-\varepsilon} \qquad 4.39$$

where the elasticity of demand $1/\varepsilon$ is the same in both markets.

Firms are based in one market and can export to the other subject to "iceberg" transport costs. The decision problem of firms is to choose capacity at the start of the product cycle, and in each time period t, choose how much to sell in each country. For a given level of capacity K_j, each firm will allocate output to the two markets such that marginal revenue is the same for both. For a representative firm j in country 1, marginal revenues can be written as:

$$MR_{j1}^{d} = p_1\left(1 - \varepsilon \frac{q_{j1}^{d}}{Q_1} v_{j11}\right) \qquad 4.40$$

$$MR_{j1}^{x} = p_2\left(1 - \varepsilon \frac{q_{j1}^{x}}{Q_2} v_{j12}\right)/(1 + z) \qquad 4.41$$

where p_1 and p_2 are prices in markets 1 and 2, q_{j1}^{d} and q_{j1}^{x} are outputs of the representative firm from country 1 in both its domestic and export markets, z is a parameter reflecting transport costs, and v_{j11} and v_{j12} are conjectural variations parameters with respect to home and foreign firms respectively. The conjectures measure the extent to which a firm expects a one unit increase in output to increase total deliveries to the market. Hence, for Cournot, the values of v_{j11} and v_{j12} would be equal to one, while for more collusive behavior, they would be greater than one. Similar expressions for a representative firm in country 2 can also be derived. This type of structure generates two-way trade in the product, and given expression (4.33), it can be shown that there will be balanced growth over the product cycle such that firms' market shares remain constant, but output rises and prices fall.

In terms of the dynamic problem, the objective of a representative firm j in country 1 is to maximize the following:

$$\pi_{j1} = \int_0^T [p_1 q_{j1}^d(t) + p_2 q_{j1}^x(t)/(1 + z)]dt - c_j K_j \qquad 4.42$$

subject to (4.34) *for all t*

T is the length of the product cycle, and following Spence (1981), it is assumed to be sufficiently short for discounting to be ignored, and it is assumed that firms follow "open-loop" strategies, i.e., they set their time-path of outputs taking other firms' output paths as given.

Given that firm j, in any period t, will equalize marginal revenues between markets 1 and 2, the marginal returns from increasing capacity K can be evaluated in terms of market 1 alone. The first-order condition is written as:

$$(1 + \theta)\int_0^T p_1(t)(1 - \varepsilon\frac{q_{j1}^d}{Q_1}v_{j11})(K_j t)^\theta dt \qquad 4.43$$

which can be re-written as[9]:

$$[(1 + \theta)/\{(1 - \varepsilon)\theta + 1\}]p_1(T)(1 - \varepsilon\frac{q_{j1}^d}{Q_1}v_{j11}) = c_j K_j^{-\theta} \qquad 4.44$$

[9] The derivation is tedious, see Krishna's (1988) comment on Baldwin and Krugman for complete working.

which in turn simplifies to:

$$P_1(1 - \varepsilon \frac{q_{j1}}{Q_1} v_{j11}) = c_j K_j^{-\theta} \qquad 4.45$$

where P_1 is the average price received over the cycle, and $c_j K_j^{-\theta}$ is the marginal cost of producing one more unit of total cycle output. This result looks essentially like marginal revenue being equated with marginal cost.

In light of expression (4.45), the dynamic problem for the firm can be collapsed into an equivalent static one where there are increasing returns. Essentially (4.45) can be interpreted in the following way: firms should act as if the true marginal cost at any point in the cycle is the direct marginal cost which is incurred at the end of the period. True marginal cost is defined as the sum of direct marginal costs plus the effects of higher production now on future production costs. Direct marginal costs fall over the cycle due to learning, however the effects of learning diminish over the cycle, and, as Spence has shown, the two effects precisely offset each other. As a result, true marginal costs remain constant throughout the cycle and will be equal to direct marginal costs at the end of the cycle. Hence, the capacity choice will be optimal if the firm simply assumes that the learning economies have already occurred and sets output to maximize profits given direct marginal costs.

An equilibrium can be defined for this simpler, static problem. As the model is characterized by balanced growth, then there will be a one-to-one relationship between total sales in each market and average price over the cycle, which will take a constant elasticity form in each market, as given by the inverse demand functions (4.38) and (4.39). Also, average cost for cumulative output over the cycle can be written for a representative firm j in country 1 as:

$$C_{j1} = C_j \chi^{-\theta/(1+\theta)} \qquad 4.46$$

Expressions (4.45), (4.46) and the inverse demand functions define the equilibrium for the static problem. Similar expressions can be defined for a representative firm in country 2.

The preceding analysis also suggests a solution procedure for this model. For any given value of marginal costs, equilibrium market prices and the market share of a representative firm can be solved for. From these, total market sales can be derived by using the inverse demand function, and given market shares, output per firm can be derived. However, this output level implies a level of marginal cost, so in order that this level of marginal cost coincides with the assumed value, i.e., the equilibrium is a fixed point, an iterative procedure is used whereby marginal costs are chosen, output is solved for, and marginal costs are re-computed until convergence of the two values for marginal cost. Once the static problem for the firm has been solved, the implied capacity choice can be derived and hence the time-path of output and prices.

Finally, Baldwin and Krugman assume free entry and exit into the market. There are many potential entrants, with the same costs and perfect foresight about the post-entry equilibrium. Given an integer constraint, this implies non-negative profits for those that enter, any further entry generating losses.

Calibrating the model is relatively straightforward. First, estimates of the elasticity of demand ε, the slope of the learning curve $\theta/(1+\theta)$, and transport costs z are taken from external estimates. Second, given assumptions about the number of symmetric, equal-cost home and foreign firms, marginal costs can be inferred in the following way. Under free entry, and ignoring integer constraints, profits should be driven to zero, such that in equilibrium, average revenue is equal to average costs for any given firm. Average revenue over the product cycle for a representative firm in country 1 is defined as:

$$AR_{j1} = \frac{\int_0^T \left[P_1(t)q_{j1}^d(t) + P_2(t)q_{j1}^x(t)/(1+z)\right]dt}{\int_0^T \left[q_{j1}^d(t) + q_{j1}(t)\right]} \qquad 4.47$$

Given average revenue, average costs can be inferred, and from this marginal cost can be computed. This is done using the expression for the elasticity of costs v, which is the ratio of marginal to average costs. In the case of learning, v is defined as $1+\theta$, so given θ and the inferred value of average cost in equilibrium, marginal cost can be derived. Given the estimate of average cost, the constant term C_j in the average cost function (4.46) can also be solved for. Third, the conjectural variations parameters can be calculated for the home and foreign firms by solving out from the first-order conditions, given data on the elasticity of demand, marginal costs and market shares.

Given this calibration, the model can then be used for simulation. In order to calculate policy effects, the simulation is conducted in two stages. First, the initial number of firms in the market is taken and the equilibrium prices and outputs implied by the policy change are computed by the iterative procedure on marginal cost just described. Second, given these prices and outputs, the entry equilibrium is derived. Importantly, the interest is in determining the effects of protection on the international competitiveness of firms where there are learning economies (see Krugman, 1984).

Finally, the calibration model of Venables and Smith is considered. In some ways this is the most general IPECAC in that it deals with imperfectly competitive market structures, economies of scale and product differentiation; however, it is also the least transparent of the models. In its most developed form, the model has been applied to simulating the completion of the European Community's (EC's) internal market. For simplicity, the presentation here refers to a domestic market (subscript 1) and the world market (subscript 2).

The focus is specifically on the domestic market, where it is assumed that the number of firms is small relative to the number in the world market, i.e., a small country assumption. As a result, the number of firms in the world market can be treated as a constant. On the demand side, in order to allow for product differentiation in the relevant industry, functions are specified for both aggregate industry output and also individual product types. For market i, the welfare function is written as:

$$S_i = [\eta/(\eta - 1)]B_i^{1/\eta}Q_i^{(\eta-1)/\eta} - P_iQ_i \qquad 4.48$$

where Q_i is a quantity index, P_i is a price index, and B_i is a parameter measuring the size of market i. The relevant aggregate demand function can be written as:

$$Q_i = B_iP_i^{-\eta} \qquad 4.49$$

where η is the elasticity of demand, which is assumed constant and the same across the two markets.

Each market is supplied by firms in both the domestic and world markets. In the domestic market there are n symmetric[10] firms each producing m brands, selling q_{1i} of each brand to market i. The world market has an exogenously determined number of firms and brands normalized to one. The sales of a brand from the world market

[10] The full version of the model does allow firms to be sub-divided into different size classes, however, this has been dropped here for simplicity.

to market i are denoted as q_{2i}. Re-defining the quantity index (4.47):

$$Q_i = [b_{1i} n m q_{1i}^{(\varepsilon-1)/\varepsilon} + b_{2i} q_{2i}^{(\varepsilon-1)/\varepsilon}]^{\varepsilon/(\varepsilon-1)} \qquad 4.50$$

where b_{1i} and b_{2i} are parameters reflecting the shares of products from the domestic and world markets in market i. Q_i can be thought of as a sub-utility function of the form suggested by Dixit and Stiglitz (1977).

Dual to this quantity index is a price index, where the world price is normalized at unity. The price in the domestic market is defined as:

$$P_1 = [b_{11}^{\varepsilon} n m p_{11}^{1-\varepsilon} + b_{21}^{\varepsilon} p_{21}^{1-\varepsilon}]^{1/(1-\varepsilon)} \qquad 4.51$$

where p_{11} and p_{21} are the prices of a brand sold in market 1 by firms from the domestic and world markets respectively, and b_{11} and b_{21} are scaling parameters determining market shares of a brand in the domestic market. The demand functions for a single brand sold in market i are:

$$q_{1i} = p_{1i}^{-\varepsilon} b_{1i}^{\varepsilon} P_i^{\varepsilon} Q_i \qquad 4.52$$

$$q_{2i} = p_{2i}^{-\varepsilon} b_{2i}^{\varepsilon} P_i^{\varepsilon} Q_i \qquad 4.53$$

where ε is the elasticity of demand for a single brand, which is assumed constant and the same for both markets. Demand for each brand depends, therefore, on both its own price and the industry price index.

On the supply side, each firm in the domestic market has two types of output choice, the number of brands m to produce and the quantity of each brand to be sold. The profits of a representative domestic firm are:

$$\pi_1 = m \sum_{i=1}^{2} q_{1i}[p_{1i} - c_1(q_{1i}, m)] \qquad 4.54$$

where $c_1(q_{1i}, m)$ is the firm's cost function, which is assumed to take the following form:

$$c_1(q_{1i},m) = mc_1(q_{11} + q_{12}) + f(m) \qquad 4.55$$

such that if the number of brands m is held constant, production incurs a fixed cost f(m), and the marginal costs of increasing output of one brand are c_1, i.e., there are increasing returns to scale. Adding an additional brand raises operating costs by $c_1(q_{11}+q_{12})$ and fixed costs by $f'(m)$. Hence the shape of f(m) may capture economies of scope.

If the domestic firm sets the price of each brand to maximize profits in both the domestic and world markets, the first-order condition can be written as:

$$p_{1i}(1 - \frac{1}{e_{1i}}) = c_1 \qquad 4.56$$

where e_{1i} is the perceived elasticity of demand, which depends on both the elasticity of demand for a single brand and also the perceived effect of the firm's action on industry supply:

$$e_{1i} = \frac{\delta q_{1i}}{\delta p_{1i}}\frac{p_{1i}}{q_{1i}} = \left[-\varepsilon + (\varepsilon - \eta)\frac{p_{1i}}{P_i}\frac{\delta P_i}{\delta p_{1i}}\right] \qquad 4.57$$

If firms believe that their actions have no effect on market price, the latter term on the right hand side of (4.57) would be zero; thus, the perceived elasticity of demand coincides with the actual elasticity of demand ε. This would be the Chamberlinian large numbers case, firm's market power deriving from the extent of product differentiation alone as reflected in ε.

Firms also choose the number of brands for maximum profits, where the first-order condition for a domestic firm can be written as:

$$\sum_{i=1}^{2} q_{1i}(p_{1i} - c_1)(1 + \Theta_{1i}) = f'(m) \qquad 4.58$$

where:

$$\Theta_{1i} = \frac{m}{q_{1i}}\frac{\delta q_{1i}}{\delta m} = \frac{(\varepsilon - \eta)}{(1 - \varepsilon)}\left[mn\frac{p_{1i}q_{1i}}{P_i Q_i}w_{1i}\right] \qquad 4.59$$

This is the perceived elasticity of sales per brand with respect to the number of brands offered, where w_{1i} is the conjectured increase in other firms' brands.

(4.58) indicates that the increment to revenue of adding a brand, net of marginal operating costs c_1, weighted by the change in sales of existing brands m, is set equal to the marginal cost of adding a new brand. The term Θ_{1i} is the conjecture that the firm makes about the effect of adding a brand on the industry aggregate sales and price indices and, hence, on the sales per brand in the domestic and world markets. Essentially, the conjecture about brands is based on beliefs about industry aggregates, so the model is analogous to a homogeneous product oligopoly.

For the foreign firms, it is assumed that the number of firms and brands is fixed. Consequently, the relevant first-order condition will be:

$$p_{2i}(1 - \frac{1}{e_{2i}}) = c_2 \qquad 4.60$$

where e_{2i} collapses to ε under the Chamberlinian assumption. Equations (4.48) to (4.60) characterize the equilibrium of this model, and, in addition, if free entry and exit are allowed for in the domestic market in response to policy changes, then expression (4.54) is set equal to zero.

In running a simulation through the model, it is assumed that at the base-line, free entry has driven profits to zero; however, in evaluating policy changes, three stages can be followed. First, output per brand adjusts to a policy change, given fixed numbers of brands and firms. The focus here is on an industry with a fixed market structure and differentiated products. Second, the number of brands is allowed to adjust; consequently, given the structure of conjectures in (4.59), oligopolistic interaction is allowed for. Third, free entry is allowed, so that the model is characterized by a structure of monopolistic competition with intra-industry trade. Consequently, the model captures two levels of competition; firms interact oligopolistically in terms of brands but play out a monopolistically competitive outcome in terms of pricing. Also, two types of welfare effects due to government intervention can be measured. First, if output per brand of the domestic firms increases, there is fuller realization of economies of scale; second, if existing firms and entrants increase the number of brands, consumers benefit from greater variety.

The model is calibrated in the following manner. First, base-line data are required on prices quantities and trade for the domestic market. Second, data are required on the cost functions of firms in a chosen industry. Venables and Smith use engineering estimates of both economies of scale and scope, and then choose parameters of the cost function to satisfy these reported properties. Third, data are required on the elasticities of demand η and ε, and the perceived elasticity Θ_{1i}. The aggregate industry elasticity η is obtained from external econometric estimates, while ε and Θ_{1i} are derived from expressions (4.54) and (4.56) and the zero profit condition under free entry. Given data on sales and costs, the mark-up of price over marginal cost consistent with zero profits generates an estimate of ε, and similarly Θ_{1i} can be solved for from (4.56).

4.2.4 Summary of Calibration/Simulation Models

The development and use of IPECACs is a very recent phenomenon, the previous sections representing a fairly detailed coverage of most of this literature. The fixed numbers models of Dixit (1988b) and Thursby and Thursby (1990) are both based on similar, linear demand structures and model oligopolistic interdependence through the use of conjectural variations, where the latter are derived through manipulation of firms' first-order conditions. Apart from the context in which the models are set, the critical difference between them is the method of calibration. Dixit calibrates all the demand system parameters by solving a system of simultaneous equations, while Thursby and Thursby (1990, 1991) estimate the demand parameters econometrically. Also, Dixit derives aggregate conjectural variations parameters, while Thursby and Thursby (1990) separate conjectures for home and foreign reactions and are able to approximate their variances. Note, however, that Thursby and Thursby (1991) aggregate the conjectures in their policy simulations.

The free entry models of Baldwin and Krugman and Venables and Smith are based on very different market structures, although both generate intra-industry trade, allow for increasing returns, and compute conjectural variations from firms' first-order conditions. Baldwin and Krugman's model, based on the "reciprocal" dumping models of Brander and Brander and Krugman, is notable for its characterization of dynamic learning economies in a one-shot static game and the use of the free entry condition to infer marginal cost. Venables and Smith's model, which is largely in the tradition of Krugman's (1979) earlier work on intra-industry trade, is characterized by both the two stages of competition in terms of numbers of brands and output per brand and also the characterization of economies of scale and scope. In terms of calibration, both adopt very similar techniques, based on external estimates of parameters and inference.

The analysis indicates several points that need to be taken into account when adopting this type of methodology. First, the type of model used to capture imperfect competition and trade has to be chosen. All those presented in the previous sections are based on variations of models developed in the recent theoretical literature on imperfect competition and international trade, although the model choice has partly been dictated by the specific industry(ies) under study. Second, the methods of model solution and calibration are important factors to be decided. Third, the nature of the data required for calibration and simulation is critical. **Table 4.1** presents a summary of the main features of these models which might be thought of as a check-list of factors that would be relevant in the development of other models.

4.3 Uses of Calibration/Simulation Models

Once the above models are calibrated they can be used for simulation, what Richardson (1990) has called "counterfactual" exercises. Essentially, the models described are maintained as true, and generate the observed data for the base-line period. The counterfactual step is to arbitrarily alter one of the variables in the model, assuming the other parameters remain constant. The new equilibrium is then calculated and compared with the base-line equilibrium. Hence, the aim is not to test the validity of the underlying model, but to gain an idea of the broad effects of trade policy, assuming such market structures exist.

In all studies, it has been normal to adjust policy variables, e.g., tariffs and subsidies are implemented, and then to calculate the net welfare effects in terms of consumer and producer surplus and net government revenue. Different methods have been adopted in these studies for handling the policy variables. Dixit (1988a) uses expressions for optimal tariffs and production subsidies which have been derived by assuming the domestic government maximizes economic welfare. In the case where government uses both a tariff and a production subsidy,[11] the explicit solutions for the tariff and the

[11] The full optimum is where both a tariff and a subsidy are implemented. Constrained optima can also be derived where either the tariff or the subsidy are implemented. In this case, different expressions for the policies are derived.

Table 4.1 Summary of Main Features of Calibration/Simulation Models

	Dixit	Thursby and Thursby	Baldwin and Krugman	Venables and Smith
Market Structure	Domestic firms competing with importers	Marketing board competing with private exporters in world market	'Reciprocal' dumping model of oligopoly	Domestic firms competing in domestic and world markets
Size Distribution of Firms	Symmetric	Symmetric	Symmetric	Symmetric-sized firms within size-classes
Entry Assumption	Fixed number of firms	Fixed number of firms	Free entry/exit	Free entry/exit
Product Differentiation	Domestic products not necessarily substitutable with imports	Goods not perfectly substitutable	None	Firms produce range of brands
Costs	Constant average and marginal costs	Constant costs	Learning economies	Economies of scale and scope, fixed costs plus constant marginal costs
Strategic Interaction	Conjectural variations	Conjectural variations	Conjectural Variations	Conjectural variations in terms of brand price and brand numbers
Structure of Trade	Imports only	Exports only	Intra-industry trade	Intra-industry trade
External Parameters and Data	Prices and quantities, elasticities of demand and substitution, marginal costs	Prices, quantities and numbers of firms	Prices and quantities, elasticities of demand and learning, transport costs	Prices and quantities, aggregate elasticity of demand, engineering estimates of scale economies
Calibrated Parameters	Solve out simultaneous equation system for demand parameters. Conjectural variations derived from first-order conditions. Cournot-equivalent number of firms compared to actual number.	Conjectural variations derived from estimates of inverse elasticities of demand. Can be compared to Cournot and Bertrand behavior.	Marginal costs inferred from elasticity of costs given free entry. Conjectural variations estimated from first-order conditions. Time-path of outputs and prices.	Parameters of cost function. Elasticity of demand for single brand, and conjectures about effect of changes in brand numbers estimated from first-order conditions.

production subsidy can be written as:

$$t = \frac{-(a_1 - c_1)kV_2 + (a_2 - c_2)b_1V_2}{(b_2 + 2V_2)b_1 - k^2} \qquad 4.61$$

$$s = \frac{(a_1 - c_1)V_1(b_2 + 2V_2) - (a_2 - c_2)kV_1}{(b_2 + 2V_2)b_1 - k^2} \qquad 4.62$$

Expressions (4.61) and (4.62) show that the optimal tariff and subsidy are affected by the relative cost levels of the domestic and foreign firms, firms' conjectural variations and also the parameters of the demand system. Consequently, after calibration of the model, values for these policies can be derived and their welfare effects calculated. Alternatively, it is possible to compare optimal policies with those actually implemented in a given market. In addition, McCorriston and Sheldon have shown that Dixit's (1988a) optimal tariff and subsidy should be adjusted in response to changes in market structure, and they have simulated the resultant welfare effects.

Venables and Smith also simulate the effects of tariffs and export subsidies through their model, although these are not based on any optimization problem for the domestic government. In contrast, Thursby and Thursby (1991) and Baldwin and Krugman have simulated the removal of implicit import tariffs through their models. In the case of Thursby and Thursby (1991), because Japan limits wheat imports through a combination of import licenses and high resale prices, they proxy this type of protection via an implicit tariff which is calculated as the difference between the c.i.f import price and the resale price. Baldwin and Krugman use an implicit import tariff for the Japanese superconductor sector because, although no formal tariffs and quotas have been in place, there is circumstantial evidence for a closed Japanese market. Specifically, it has been claimed that the Japanese government has encouraged Japanese users of superconductors to buy from Japanese firms, so there has been an implicit form of protection in place.

Table 4.2 summarizes the applications made to date of the models described in Section 2, focussing on the markets to which they have been applied and the policy experiments conducted. Although the purpose of this paper has been to focus on the mechanics of using IPECACs rather than the evaluation of simulation results, a broad indication of the simulated welfare gains is also included in the table.[12]

4.4 Limitations of the Technique

In evaluating the use of IPECACs, it is useful to distinguish between the underlying theoretical models and the technique itself. As far as the models are concerned, they are essentially extensions of theoretical work already developed in the international economics literature. In that respect, IPECACs are important and innovative extensions to this literature; however, they are also subject to the same kind of problems. In particular, the predictions of the models are fairly sensitive to the underlying assumptions. However, in defense of the models, they are designed, in many respects, to characterize specific industries - Baldwin and Krugman's model being a particularly good example. Therefore IPECACs are partly following in the tradition of the recent work in industrial organization where individual industries are taken to have important idiosyncracies.[13]

The theoretical analysis underlying IPECACs can be criticized for two important technical reasons, which have been acknowledged by all those working in this area. The first is the use of conjectural variations to characterize oligopolistic behavior. Conjectural variations have long been regarded as an unsatisfactory way of modelling oligopoly, the standard objection being that they represent an attempt to impose dynamic interaction of firms on a single-period game (see Tirole, 1989, and Helpman and Krugman). If firms are playing a one-period noncooperative game, where they choose either output or price simultaneously and independently, then the Nash equilibrium (Cournot or Bertrand) is the standard maximizing outcome. However, a static game, by definition, cannot allow firms to react to one another, and so the notion of firms having beliefs about their rivals' reactions is unsatisfactory.

In addition, as Helpman and Krugman and Dixit (1988b) point out, when conducting comparative statics exercises with calibration models, the conjectural variations parameters are treated as fixed. However, there is no reason why this should be so, particularly in light of the results of Harris (1985) and Krishna (1989) who have shown

[12] See Richardson for a more complete survey of the results of calibration models.

[13] See Bresnahan (1989) for a survey.

Table 4.2 Uses of Simulation Models

	Market	Policy Experiment	Welfare Effects
Dixit (1988b)	U.S.-Japanese competition in U.S. automobile market	Implementation of optimal tariffs and subsidies	Small
Laussel *et al* (1988)[1]	European-Japanese competition in European automobile market	Elimination of voluntary export restraints and implementation of optimal tariffs and subsidies	Small
Thursby and Thursby (1991)	U.S.-Canadian competition in wheat exports to Japan	Removal of Japanese import restrictions, U.S. and Canadian producer subsidy equivalents	None calculated
McCorriston and Sheldon (1991)[1]	UK fertilizer industry competition with Eastern bloc imports	Implementation of optimal tariffs and subsidies and adjustments with respect to changes in market structure	Small
Baldwin and Krugman (1988)	U.S.-Japanese competition in superconductors	Removal of Japanese trade barriers and simulation of trade war	Japanese firms exit, increase in consumer surplus and U.S. firms' profits after removal of Japanese barriers. Trade war reduces U.S. and Japanese welfare
Venables and Smith (1986)	UK-world competition in refrigerators and footwear	Implementation of import tariffs, export and production subsidies and simulation of trade war	Moderate
Digby, Smith and Venables (1988)	European-Japanese competition in European automobile market	Removal of voluntary export restraints	Moderate
Smith and Venables (1988)	Sample of industries in the European Community	Removal of non-tariff barriers through EC 1992 process	Moderate

1. Use Dixit's (1988b) model

developed to assess the welfare implications of the use of trade policies where international markets are imperfectly competitive. In order to get a feel for this methodology, the four best-known simulation/calibration models have been outlined in some detail, focussing on the underlying theoretical structure, the solution and calibration procedures, the type of external data required and the policy simulations run.

In conclusion, IPECACs need to be used with a certain amount of caution and a recognition that they are not a particularly sophisticated form of analysis, both theoretically and empirically. Also, it is important to understand that because the technique maintains the underlying theoretical model as true, their use is limited to "counterfactual" exercises of the type discussed, so the models give us only a "snap-shot" of the actual nature of competition in international markets. Nonetheless, they do represent an interesting contribution to the analysis of trade policy where markets are imperfectly competitive. Baldwin (1989), in describing his own simulation work, best sums up the calibration/simulation methodology:

"The results should be thought of as rough, back-of-the-envelope calculations. Samuel Johnson's quip about a dog walking on its hind legs applies to my empirical work: the interest lies not in that it is done well, but rather that it is done at all". (p.249)

References

Baldwin, R. 1989. "The Growth Effects of 1992", *Economic Policy, 9*: 247-281.

Baldwin, R. and Krugman, P.R. 1988. "Market Access and International Competition: A Simulation Study of 16K Random Access Memories." In *Empirical Methods for International Trade*, edited by R.Feenstra. Cambridge, MA: M.I.T. Press.

Brander, J.A. 1981. "Intra-Industry Trade in Identical Commodities", *Journal of International Economics, 11*: 227-242.

Brander, J.A. and Krugman, P.R. 1983. "A Reciprocal Dumping Model of Intra-Industry International Trade", *Journal of International Economics, 13*: 313-321.

Brander, J.A. Spencer, B.J. 1985. "Export Subsidies and International Market Share Rivalry", *Journal of International Economics, 18*: 83-100.

Bresnahan, T.F. 1989. "Empirical Studies of Industries with Market Power." In *Handbook of Industrial of Industrial Organization*, edited by R.Schmalensee and R.Willig. Amsterdam: North Holland.

Cox, D. and Harris, R. 1985. "Trade Liberalization and Industrial Organization: Some Estimates for Canada", *Journal of Political Economy, 93*: 115-145.

Digby, C., Smith, A. and Venables, A. 1988. "Counting the Cost of Voluntary Export Restrictions in the European Car Market", Centre for Economic Policy Research Discussion Paper, No. 249.

Dixit, A. 1986. "Comparative Statics for Oligopoly", *International Economic Review, 27*: 107-122.

__________ 1988a. "Anti-Dumping and Countervailing Duties under Oligopoly", *European Economic Review, 32*: 55-68.

__________ 1988b "Optimal Trade and Industrial Policies for the U.S. Automobile Industry." In *Empirical Methods for International*

Trade, edited by R.Feenstra. Cambridge, MA: M.I.T, Press.

Dixit, A. and Stiglitz, J.E. 1977. "Monopolistic Competition and Optimum Product Diversity", American Economic Review, 67: 297-322.

Eaton, J. and Grossman, G.M. 1985. "Optimal Trade Policy under Oligopoly", *Quarterly Journal of Economics, 101*: 383-406.

Helpman, E. and Krugman, P.R. 1989. *Trade Policy and Market Structure*. Cambridge, MA: M.I.T. Press.

Harris, R. 1985 "Why Voluntary Export Restraints are 'Voluntary'", *Canadian Journal of Economics, 18*: 799-801.

Krishna, K. 1988. "Comment on 'Market Access and International Competition'." In *Empirical Methods for International Trade*, edited by R. Feenstra. Cambridge, MA: M.I.T. Press.

__________ 1989. "Trade Restrictions as Facilitating Practices", *Journal of International Economics, 26*: 251-270.

Krugman, P.R. 1979. "Increasing Returns, Monopolistic Competition and International Trade", *Journal of International Economics, 9*: 469-479.

__________ 1984. "Import Protection as Export Promotion: International Competition in the Presence of Oligopoly and Economies of Scale." In *Monopolistic Competition in International Trade*, edited by H.Kierzkowski. Oxford: Oxford University Press.

__________ 1986. "Comment on 'Trade and Industrial Policy under Imperfect Competition'", *Economic Policy, 3*: 660-663.

Laussel, D., Montet, C. and Peguin-Feisolle, A. 1988. "Optimal Trade Policy under Oligopoly-A Calibrated Model of the Europe-Japan Rivalry in the EEC Car Market", *European Economic Review, 32*: 1547-1565.

Love, H.A. and Murniningtyas, E. 1990. "Measuring the Degree of Market Power Exerted By Government Trade Agencies", *Organization and Performance of World Food Systems: NC-194*, *Occasional Paper,* OP-16.

McCorriston S. and Sheldon I.M. 1991. "Government Intervention in Imperfectly Competitive Agricultural Input Markets", *American Journal of Agricultural Economics 73:* 621-632.

Norman, V. 1989. "Trade Policy under Imperfect Competition-Theoretical Ambiguities-Empirical Regularities", *European Economic Review, 33*: 473-479.

Richardson J.D. 1990. "International Trade, National Welfare, and the Workability of Competition: A Survey of Empirical Estimates." In *Imperfect Competition and Political Economy-The New Trade Theory in Agricultural Trade Research,* edited by C.A.Carter, A.F.McCalla and J.A. Sharples. Boulder, CO: Westview Press.

Smith, A. and Venables, A. 1988. "Completing the Internal Market in the European Community-Some Industry Simulations", *European Economic Review, 32*: 1501-1525.

Spence, A.M. 1981. "The Learning Curve and Competition", *The Bell Journal of Economics, 12*: 49-70.

Thursby, M.C. 1988. "Strategic Models, Market Structure and State Trading: An Application to Agriculture." In *Trade Policy and Empirical Analysis*, edited by R.E. Baldwin. Chicago: University of Chicago Press, IL.

Thursby, M.C. and Thursby, J.G. 1990. "Strategic Trade Theory and Agricultural Markets: An Application to Canadian and U.S. Wheat Exports to Japan." In (eds.), *Imperfect Competition and Political Economy-The New Trade Theory in Agricultural Trade Research*, edited by C.A.Carter, A.F.McCalla and J.A. Sharples. Boulder, CO: Westview Press.

__________ 1991. "Strategic Trade Theory and Agricultural Markets: An Application to Canadian and U.S. Wheat Exports to Japan", *Organization and Performance of World Food Systems: NC-194, Occasional Paper*, OP-21.

Tirole, J. 1989. *The Theory of Industrial Organization*. Cambridge, MA: M.I.T. Press.

Venables, A. and Smith A. 1986. "Trade and Industrial Policy under Imperfect Competition", *Economic Policy, 3*: 622-672.