The work reported herewithin contributes to the objectives of the North Central Regional Project NC-194, a joint research project of state agricultural experiment stations and the U.S. Department of Agriculture.
IMPERFECT COMPETITION AND INTERNATIONAL TRADE: THE USE OF SIMULATION TECHNIQUES

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OP-24 APRIL 1991

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PAPER PRESENTED AT THE WORKSHOP ON INDUSTRIAL ORGANIZATION AND INTERNATIONAL TRADE, NC-194, COLUMBUS, OHIO, APRIL 24-25, 1991
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 to 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) 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

\(^1\) 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.
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. Some of the parameters are taken from external estimates, while the rest are calibrated to the model in order to reproduce the chosen base-period data. The models are used to simulate changes in policy regimes, such as the imposition of import tariffs, and then 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 1 examines in some detail the types of theoretical model that have been developed and the process of model calibration. In order to keep the analysis manageable, only industry-level, partial equilibrium models will be considered. Section 2 considers the types of problem such techniques have been used to address, while in Section 3, the limitations of the technique are outlined.

1. Calibration/Simulation Models

While several theoretical models have been developed in the calibration/simulation literature, in keeping with Helpman and Krugman (1989), it is useful to 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 similar analysis by 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 developed 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 product markets. Second, free-entry models imply that in equilibrium, prices will equal average costs, consequently, in cases where cost data are unavailable, inferences can be made about costs from the observed market outcome.

(i) Models with Fixed Market Structure

(a) The earliest example of an IPECAC is that developed by Dixit, which he applied to the US 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

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\(^3\) If an integer constraint is observed, there can be positive profits in equilibrium that would disappear with further entry.
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. So a representative consumer maximizes surplus as given by:

\[
S_t = U(Q_1, Q_2) - \sum_{i=1}^{2} p_i Q_i
\]

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 quadratic:

\[
U(Q_1, Q_2) = a_1 Q_1 + a_2 Q_2 - (b_1 Q_1^2 + b_2 Q_2^2 + 2k Q_1 Q_2)/2
\]

where \(a_i, b_i\) and \(k\) are assumed positive.

This utility maximizing problem generates the following inverse demand functions:

\[
p_1 = a_1 - b_1 Q_1 - k Q_2
\]

\[
p_2 = a_2 - b_2 Q_2 - k Q_1
\]

where \(b_1 b_2 - k^2 > 0\) if the products are imperfect substitutes, \(b_1 b_2 - k^2 = 0\) if they are perfectly substitutable. The direct demand functions can be written as:

\[
Q_1 = A_1 - B_1 p_1 + K p_2
\]

\[
Q_2 = A_2 - B_2 p_2 + K p_1
\]

where all the parameters are positive, and as above, the same conditions on \(B_1 B_2 - K^2\) apply.
The parameters of the inverse demand system can also be expressed in terms of the direct demand system as:

\[ a_1 = \frac{A_1B_2 + KA_2}{B_1B_2 - K^2}; \quad a_2 = \frac{A_2B_1 + KA_1}{B_1B_2 - K^2}; \]

\[ b_1 = \frac{B_2}{B_1B_2 - K^2}; \quad b_2 = \frac{B_1}{B_1B_2 - K^2}; \quad k = \frac{K}{B_1B_2 - K^2} \]

(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:

\[ \pi_1 = (p_1 - c_1 + s)q_1 \]

(8)

\[ \pi_2 = (p_2 - c_2 - t)q_2 \]

(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 3). 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 react to a change in its output. Hence a domestic firm 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 \( n_2v_{12} \).

\(^4\) 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.
Assuming domestic and foreign firms set output to maximize profits, the first-order conditions can be written as:

\[
(10) \quad p_1 - c_1 + s + q_1\left[\frac{\delta p_1}{\delta q_1}[1 + (n_1 - 1)v_{11}] + \frac{\delta p_1}{\delta q_2}n_2v_{12}\right]
\]

\[
(11) \quad p_2 - c_2 - t + q_2\left[\frac{\delta p_2}{\delta q_2}[1 + (n_2 - 1)v_{22}] + \frac{\delta p_2}{\delta q_1}n_1v_{21}\right]
\]

Given the \(n_1\) domestic and \(n_2\) foreign firms are assumed to be symmetric, expressions (10) and (11) can be aggregated to give:

\[
(12) \quad p_1 - c_1 + s - Q_1V_1 - 0
\]

\[
(13) \quad p_2 - c_2 - t - Q_2V_2 - 0
\]

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

\[
(14) \quad V_1 = \frac{[b_1(1 + (n_1 - 1)v_{11}) + kn_2v_{12}]}{n_1}
\]

\[
(15) \quad V_2 = \frac{[b_2(1 + (n_2 - 1)v_{22}) + kn_1v_{21}]}{n_2}
\]

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 \(V_p\), which determines the effect of domestic and foreign firms' behavior on the market outcome. Consequently, in calibrating Dixit's 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 (12) and (13). However, as will
be discussed shortly, Thursby and Thursby 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 (12) and (13) are combined with the inverse demand functions, the explicit solutions being:

\[
\begin{align*}
\begin{bmatrix}
Q_1 \\
Q_2
\end{bmatrix} &= \frac{1}{\Delta'} \begin{bmatrix}
-1 & b_2 + V_2 - k \\
-k & b_1 + V_1
\end{bmatrix} \begin{bmatrix}
a_1 - c_1 + s \\
a_2 - c_2 - t
\end{bmatrix} \\
\begin{bmatrix}
p_1 \\
p_2
\end{bmatrix} &= \frac{1}{\Delta'} \begin{bmatrix}
a_1 & b_1 V_2 - k V_1 \\
A' & b_2 V_1
\end{bmatrix} \begin{bmatrix}
a_1 - c_1 + s \\
a_2 - c_2 - t
\end{bmatrix}
\end{align*}
\]

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

(b) Turning to Thursby and Thursby’s model, this is essentially of the same generic type as Dixit’s, 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 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, \(j = 1, \ldots, n\), 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 model, the two countries’ commodities are not necessarily perfect substitutes.

The model is based on the same type of demand system described in expressions (3)-(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:

\[
R_1 = (p_1^d + r_1)Q_1^d + (p_1^x - c_1^x + x_1)Q_1^x - f_1 - \int_0^{Q_1^*} [p_1^t(q) - s_1]dq
\]

\[
\pi_j = p_2^d q_2^d + p_2^x q_2^x - p_2 f(Q_2^d + Q_2^x)(q_2^d + q_2^x) - f_2^x - f_2 - (s_2 + r_2)q_2^d + (s_2 + x_2 - c_2^x)q_2^x
\]

In expression (18) for the marketing board \( p_1^d, p_1^x, Q_1^d, Q_1^x \) are as defined, \( p_1^t(q) \) is the competitive commodity supply price, \( c_1^x \) are export transport costs, \( f_1 \) are fixed costs and \( r_1, x_1 \) and \( s_1 \) are consumer, export and marketing board subsidies respectively\(^5\). Expression (19) refers to that for a representative firm \( j \), where \( p_2^d, p_2^x, q_2^d \) and \( q_2^x \) 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, \( f_2^x \) and \( f_2 \) are the fixed costs of export and domestic operations, where for firms \( j=1,...,g \), \( f_2^x \) are lower than those for firms \( j=g+1,...,n \), i.e. export firms \( g \) have an advantage over those

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\(^5\) 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.
that compete only in the domestic market. Finally, \( r_2, x_2 s_2 \) and \( s_2 \) are consumer, export and producer subsidies respectively.

As with Dixit's 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:

\[
(20) \quad p_1^d(1 + e_1^d) - p_1^f - (s_1 + r_1)
\]

\[
(21) \quad p_1^e(1 + e_1^x + e_{12}^x \eta_{12} Q_1^x/Q_2^x) - p_1^f + c_1^x - (s_1 + x_1)
\]

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 country 2's exports. \( \eta_{12} \) 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 \( \eta_{12} = 0 \). 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 \( \eta_{12} \) can be defined as:

\[
(22) \quad \eta_{12} = \left( \frac{\delta Q_2^x}{\delta p_1^x} \middle/ \frac{\delta Q_1^x}{\delta p_1^x} \right) \bigg|_{s_2 = 0} = \frac{K}{-B_1} - \frac{k}{b_2}
\]

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

For the private firms in country 2, it is assumed that the domestic market is

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

7 See Eaton and Grossman (1985) for a derivation of this.
competitive, the focus being on the first-order condition for those firms that export. As with Dixit, there are g symmetric exporters, the first-order condition for a representative firm being:

\[(23)\]

\[p_2^x(1 + (e_2^x/g)(1 + v_{j22}) + e_{21}^x v_{j21} q_2^x/Q_2^x) - p_2^x + e_2^x - s_2 - x_s_2 + \psi q_2^x(1 + v_{j22})\]

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. \(\Psi\) is defined as \(\delta p_2^x/\delta(Q_2^d + Q_2^x)\). Again the conjectural variations terms take particular values for the Cournot and Bertrand cases. Critically, however, it is possible that \(v_{j22} > v_{j21}\).

In order to obtain equilibrium prices and quantities following a change in policy, the first-order conditions (20) and (21), g versions of (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 (16) and (17).

(ii) 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 model, if the focus is on equations (3)-(6), in order to use the model for simulation, estimates of the demand parameters are required. Inspection of (5) and (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 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.

\[8\] 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.
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 $p_1 = p_1^0 P$ and $p_2 = p_2^0 P$, where $p_1^0$ and $p_2^0$ are initial prices and $P$ is the proportional change factor, consumer expenditure can be written as:

$$Q = p_1^0 Q_1 + p_2^0 Q_2$$

Given that in calibrating the model, $p_1$ and $p_2$ will be the initial base-line prices, and given (5) and (6), then (24) can be re-written as:

$$Q = p_1 A_1 + p_2 A_2 - (B_1 p_1^2 + B_2 p_2^2 - 2K p_1 p_2) P$$

The total market elasticity of demand for the product, $\varepsilon$, is then defined and evaluated at the base-line point where $P$ equals 1. By differentiating (25) with respect to $P$, and multiplying by $P/Q$, the elasticity is given by:

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

which is then set equal to the external estimate of $\varepsilon$.

The elasticity of substitution would normally be defined as:

$$\sigma = d\log(Q_1/Q_2)/d\log(p_1/p_2)$$

which gives a fourth expression when set equal to an external estimate of $\sigma$. However, (5) and (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:

$$p_1 (A_1 K + A_2 B_1) - p_2 (A_2 K + A_1 B_2)$$

which implies homotheticity of the utility function.
From (27), and using (5),(6) and (28), the final expression for $\sigma$ is:

$$
\sigma = \frac{\frac{P_1}{P_2} (B_1B_2 - K^2)}{(B_1\frac{P_1}{P_2} - K)(B_2 - K\frac{P_1}{P_2})}
$$

Given base-line values of $p_1$, $p_2$, $Q_1$ and $Q_2$, and external estimates of $\epsilon$ and $\sigma$, estimates of the direct demand parameters $A_1$, $A_2$, $B_1$, $B_2$ and $K$ are obtained by solving the simultaneous equation system (5), (6), (26), (28) and (29). In turn (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 (16) and (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 $t$, and estimates of $c_i$ and using expressions (12) and (13). Note that Dixit 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 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 derived a value of $V_1$ for US 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 US 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.
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.

So, for the marketing board, re-arranging (21):

$$
V_{12} = -Q_1^x(\mu_1 + p_1^x e_1^x)/e_2^x p_1^x Q_1^x
$$

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

In any given year, base-line data are available for $p_1^x$, $Q_1^x$, $Q_2^x$ and $\mu_1$, but the inverse
demand elasticities $e_1^x$ and $e_{12}^x$ are not observable. Rather than follow the Dixit approach,
Thursby and Thursby choose to estimate the elasticities and then solve for the conjectural
variations term.

For the $g$ exporters in country 2, expression (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
re-arranging (23) and summing over the $g$ exporting firms:

$$
V_{j21} = -Q_2^x[\gamma_2 + p_2^x e_2^x (1 + V_{j22})]/e_2^x p_2^x Q_2^x
$$

$$
V_{j22} = -[\gamma_2 (e_2^x + e_{21}^x V_{j21} Q_2^x/Q_1^x)]/p_2^x e_2^x
$$

where $\mu_2 = (p_2^x - p_2^f - c_2^x + x_s + s_2)$
Again in any given year, $p_2^x, Q_1^x, Q_2^x$ and $\mu_2$ are available, and as with Dixit's 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 looked at US 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 estimate linear inverse demand functions of a form similar to (3) and (4) using time-series data.

In contrast to Dixit's methodology, because Thursby and Thursby 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 US exporting firms over the period 1976/77 to 1984/85. An example of their results for 1984/85 are:

<table>
<thead>
<tr>
<th>$v_{12}$ given $v_{22}$</th>
<th>$v_{12}$ given $v_{21}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.160 (-0.067)</td>
<td>-0.900 (Bertrand)</td>
</tr>
<tr>
<td></td>
<td>-0.546 (0.188)</td>
</tr>
<tr>
<td>-0.895 (-0.382)</td>
<td>-0.500 (0.116)</td>
</tr>
<tr>
<td></td>
<td>-0.715 (0.116)</td>
</tr>
<tr>
<td>-1.814 (-0.777)</td>
<td>0.000 (Cournot)</td>
</tr>
<tr>
<td></td>
<td>-0.987 (0.003)</td>
</tr>
</tbody>
</table>

Source: Thursby and Thursby (1991)
(Standard errors in parentheses)
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 US 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.

(iii) 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.

(a) 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:

\begin{equation}
\frac{y_j(t)}{[K_j]^0}
\end{equation}
Hence total output $q_j$ in any time period will be:

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

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

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

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

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

where $c_j$ is the annualized cost of a unit of capacity. Re-arranging (34) in terms of $(K_j t)$ and substituting into (36), an expression for the behavior of costs over time is:

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

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:

$$p_1 = a_1 Q_1^{1/\epsilon}$$

$$p_2 = a_2 Q_2^{1/\epsilon}$$

where the elasticity of demand $1/\epsilon$ 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. So 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:

\[ MR^d_{j1} = p_1 (1 - e^{d_j Q_1 / q_{j1}}) \]

\[ MR^x_{j1} = p_2 (1 - e^{x_j Q_2 / q_{j12}})/(1 + z) \]

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 its own 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 (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:

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

subject to (34) for all $t$

$T$ is the length of the product cycle, and following Spence (1981), it is assumed that this is sufficiently short for discounting to be ignored. Also, 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:

\[(43)\]
\[
(1 + \theta) \int_0^T P_1(t) (1 - \epsilon \frac{q_{1j}}{Q_1} v_{1j}) (K_j t) \theta dt
\]

which can be re-written as:\(^9\):

\[(44)\]
\[
[(1 + \theta)/((1 - \epsilon) \theta + 1) P_1(T)(1 - \epsilon \frac{q_{1j}}{Q_1} v_{1j}) - c_j K_j^{-\theta}
\]

which in turn simplifies to:

\[(45)\]
\[
P_1(1 - \epsilon \frac{q_{1j}}{Q_1} v_{1j}) - c_j K_j^{-\theta}
\]

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 the light of expression (45), the dynamic problem for the firm can be collapsed into an equivalent static one where there are increasing returns. Essentially (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

---

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

Therefore, 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 (38) and (39). Also average cost for cumulative output over the cycle can be written down for a representative firm $j$ in country 1 as:

$$C_{jt} = C_j x^{-0/(1+\delta)}$$

Expressions (45), (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, 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 $\epsilon$, 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:

\[
AR_{11} = \int_0^T \left[ P_1(t)q^d_{11}(t) + P_2(t)q^r_{11}(t)/(1 + z) \right] dt \int_0^T \left[ q^d_{11}(t) + q^r_{11}(t) \right]
\]

So 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 $\nu$, which is the ratio of marginal to average costs. In the case of learning, $\nu$ is defined as $1+\theta$, so given $\theta$ 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 (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).

(b) 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 Communities’ (EC’s) internal market, however, 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. So for
market i, the welfare function is written as:

\( S_i = \left[ \frac{n}{(\eta - 1)} \right] B_i^{\eta/n} Q_i^{(\eta-1)/\eta} - P_i Q_i \) 

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:

\( Q_i = B_i P_i^{-\eta} \)

where \( \eta \) 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 to market i are
denoted as \( q_{2i} \). So re-defining the quantity index (47):

\( Q_i = \left[ b_{1i} n m q_{1i}^{(e-1)/e} + b_{2i} q_{2i}^{(e-1)/e} \right] s^{(e-1)} \)

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. So the price in the domestic market is defined as:

\( P_1 = \left[ b_{11} n m p_{11}^{1-\epsilon} + b_{21} p_{21}^{1-\epsilon} \right] u/(1-\epsilon) \)

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 \( b_{1i} \) and \( b_{2i} \) are scaling parameters determining market

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\(^{10}\) 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.
shares of a brand in the domestic market. The demand functions for a single brand sold in market \( i \) are:

\[
q_{1i} = p^{i*}_{1i} b^i_{1} p^i_{1} Q_i
\]

\[
q_{2i} = p^{i*}_{2i} b^i_{2} p^i_{2} Q_i
\]

where \( \epsilon \) 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:

\[
\pi_1 = m \sum_{i=1}^{2} q_{1i} [p_{1i} - c_i(q_{1i} m)]
\]

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

\[
c_i(q_{1i} m) = mc_i(q_{1i} + q_{12}) + f(m)
\]

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 \( c_i \), i.e. there are increasing returns to scale. Adding an additional brand raises operating costs by \( c_i(q_{1i} + q_{12}) \) and fixed costs by \( f'(m) \). Hence the shape of \( f(m) \) may capture economies of scope.

Therefore, 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:

\[
p_{1i}(1 - \frac{1}{\epsilon_{1i}}) - c_i
\]

where \( \epsilon_{1i} \) 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:

\[(57)\]

\[e_{11} = \frac{\delta q_{11} P_{11}}{\delta P_{11} q_{11}} - \left[ -e + (\eta) \frac{P_{11} \delta P_{1}}{P_{1} \delta P_{11}} \right]\]

If firms believe that their actions have no effect on market price, the latter term on the right hand side of (57) would be zero, thus the perceived elasticity of demand coincides with the actual elasticity of demand \(e\). This would be the Chamberlinian large numbers case, firm's market power deriving from the extent of product differentiation alone as reflected in \(e\).

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

\[(58)\]

\[\sum_{i=1}^{2} q_{ii}(P_{ii} - c_{i})(1 + \Theta_{ii}) - f'(m)\]

where:

\[(59)\]

\[\Theta_{ii} = \frac{m}{q_{ii}} \frac{\delta q_{ii}}{\delta m} - \frac{(e - \eta)}{(1 - e)} \left[ mn \frac{P_{ii} q_{ii}}{P_{i} Q_{i}} w_{ii} \right]\]

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

(58) indicates that the increment to revenue of adding a brand, net of marginal operating costs \(c_{i}\), weighted by the change in sales of existing brands \(m\), is set equal to the marginal cost of adding a new brand. The term \(\Theta_{ii}\) 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:

\[ p_{2i}(1 - \frac{1}{e_{2i}}) - c_2 \]

where \( e_{2i} \) collapses to \( e \) under the Chamberlinian assumption. Equations (48) to (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 (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 (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 effect due to government intervention can be measured. First, if output per brand of domestic firms increases, there is fuller realization of economies of scale; second, if existing firms and entrants increase the number 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 $\eta$ and $\varepsilon$, and the perceived elasticity $\Theta_{II}$. The aggregate industry elasticity $\eta$ is obtained from external econometric estimates, while $\varepsilon$ and $\Theta_{II}$ are derived by solving out from expressions (54) and (56) and the zero profit condition under free entry. So given data on sales and costs, the mark-up of price over marginal cost consistent with zero profits, generates an estimate of $\varepsilon$, and similarly $\Theta_{II}$ can be solved for from (56).

(iv) 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 and Thursby and Thursby 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 estimate the demand parameters econometrically. Also, Dixit derives aggregate conjectural variations parameters, while Thursby and Thursby separate conjectures for home and foreign reactions and are able to
approximate their variances. Note, however, that Thursby and Thursby 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 method 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 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.
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Table 1 Summary of Main Features of Calibration/Simulation Models
2. 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 uses expressions for optimal tariffs and production subsidies which have been derived by assuming the domestic government maximizes economic welfare. So in the case where government uses both a tariff and a production subsidy\(^1\), the explicit solutions for the tariff and production subsidy can be written as:

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

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

\[^1\] 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.
Expressions (61) and (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 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 and Baldwin and Krugman have simulated the removal of implicit import tariffs through their models. In the case of Thursby and Thursby, 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 such there has been an implicit form of protection in place.

Table 2 summarizes the applications made to date of the models described in Section 1, focussing on the markets to which they have been applied and the policy experiments
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1. Use Dixit's model
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\textsuperscript{12}.

3. 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\textsuperscript{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

\textsuperscript{12} See Richardson for a more complete survey of the results of calibration models.

\textsuperscript{13} See Bresnahan (1989) for a survey.
firms on a single-period game (see Tirole, 1989, and Helpman and Krugman). If firms are
playing a one-period non-cooperative 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 one another, and so the notion of firms having beliefs about their rivals' reactions is
unsatisfactory.

In addition, as Helpman and Krugman and Dixit 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 that firms will act more
collusively than Bertrand when voluntary export restraints are imposed in a specific market.
Unfortunately, if conjectures are varied arbitrarily in simulation analysis, then virtually any
equilibrium can be sustained following a policy change.

Notwithstanding these criticisms, conjectural variations are usually adopted in
empirical work on imperfect competition. The standard defense is twofold; first, conjectural
variations, if treated as parameters, can capture a range of oligopolistic behavior. This is
important in light of Eaton and Grossman's (1985) result that the choice of optimal trade
policy can be highly sensitive to the underlying game being played by firms. Hence, the
empirical work is able to avoid some of the ambiguities of the theoretical analysis by
allowing the data to determine the nature of competition in a specific market rather than
impose a specific form on the model. Second, their use is often defended on the grounds
of tractability and the lack of a suitable alternative (see Dixit, 1986). Krugman (1986) has neatly summarized the justification for using conjectural variations,

"The only justification for committing conjectural variations is that nothing else is available. In the meantime, while we wait for tungsten steel to be invented, we will chip away at the problem with our blunt stone axes." (p.662).

The second technical criticism is that the models generally assume an industry is made up of a number of symmetric-sized firms, which is empirically unreasonable. Researchers get around the problem by using the numbers-equivalent of the Herfindahl index such that, a number of actual, non-symmetric firms are treated as if they are a smaller number of symmetric firms. The defense of this is again one of tractability and the lack of any suitable models within which to allow for a non-uniform size distribution of firms.

Turning to the technique itself, two potential limitations can be pointed out which have already been noted elsewhere in the literature (see Richardson). First, calibration exercises do not allow the data used to reject the underlying theoretical model, which is maintained throughout the simulation process. Consequently, the research conducted has simply been an empirical exercise in comparative statics to which no statistical robustness can be attached. However, IPECACs are probably no worse than other kinds of simulation methods used by economists. Also, the work of Thursby and Thursby is an indication that greater efforts can be made to test parts of the underlying models.

Second, the technique has been criticized for its "selective and judgmental use of data" (Richardson, p.53). For example, McCorriston and Sheldon, in their analysis of the

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14 Krugman (1986) reports Whalley as describing calibration techniques as "non-stochastic estimation"!
UK fertilizer industry, were forced, through lack of precise data, to use an external estimate of the elasticity of demand based on empirical work conducted in the 1960s and an estimate of the elasticity of substitution between domestically produced fertilizers and imports based on an Australian estimate. Also, Venables and Smith, in calibrating their cost function for the UK refrigerator and footwear industries, use estimates derived in the 1960s.

The use of data on elasticities from earlier econometric studies has been specifically commented on by Love and Murniningtyas (1990). They suggest that many of the estimates used in simulation studies are based on market structures of perfect competition. Therefore, they argue that there is a discrepancy between the maintained hypothesis of the simulation and that of the models used to estimate the elasticities, and the simulations, therefore, could lead to misleading conclusions.

However, in partial defense of the method, most analyses make some effort to conduct sensitivity analysis on the chosen external parameter estimates. For example, Dixit varies the values of costs and elasticities, while Baldwin and Krugman vary the values of transport costs, the elasticity of demand and learning economies. In changing these external parameters, the models have to be re-calibrated, consequently other model parameters change. Baldwin and Krugman, in using quite wide ranges for their parameters, conclude that, "we need not worry too much about the accuracy of 'outside' parameters" (p.194), while Dixit indicates that his results are not particularly sensitive to changes in the elasticities but are sensitive to changes in the values of costs. Clearly these are not sophisticated tests, but they are a useful way of checking the direction and magnitude of the welfare changes.
4. Summary and Conclusion

In this paper, the use of industry-level calibration/simulation models has been outlined and reviewed. These models have been 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


