An Independent Assessment of the SALTER General Equilibrium Model of the World Economy

by

Thomas W. Hertel

Senior Fulbright Research Fellow, IMPACT Project

and

Associate Professor, Purdue University

West Lafayette, Indiana

SALTER Working Paper No. 8

MARCH 1991

I. Overview and Purpose of the Review

The purpose of this review is to provide an independent, external assessment of the work conducted by the Industries Commission (IC) for the Department of Foreign Affairs and Trade (DFAT). Under this contract, the IC agreed to develop a model of international trade, with an emphasis on the Pacific Rim. The first stage of this work has now been completed. The resulting product is named the SALTER model. This review is based on the documentation of the work-to-date contained in a recently released Draft Working Document.*

While further refinements of the SALTER framework continue to be made, the existing model has thus far been used to explore the implications of (i) unilateral agricultural trade liberalization in Japan, and (ii) the implications of an oil price shock. An additional, multilateral trade liberalisation experiment is currently underway.

The specific terms of reference of this review are as follows:

(1) To assess how this work fits in with existing research in this area, and what its overall contribution is.

(2) To determine whether the model embodies "attainable best practice" methods.

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* Industry Commission, SALTER : A General Equilibrium Model of the World Economy, Draft Working Document, Canberra, January 1991.

(3) To assess the strengths and weaknesses of this work.

(4) To consider the range of issues which the model is capable of addressing.

(5) To suggest improvements which should be considered for future work with this model.

(6) To assess whether the IC met the terms of reference laid out in the Memorandum of Agreement between the Industry Commission and the Department of Foreign Affairs and Trade.

The structure of this review is as follows. In section II, I summarize the overall contribution of this project, and how it fits in with existing research efforts in this area. I then turn to a discussion of the salient features of the model structure (section III) and data (section IV) with an eye for strengths and potential limitations of the model, as well as suggestions for future improvements. This is followed by an overall assessment of the project (section V).

II. Overall Contribution of the Work

Development of the SALTER model has drawn heavily on two distinct lines of research. As noted in the IC report, the OECD's work with the WALRAS model of international trade played an important role in inspiring this project. Indeed, the initial proposal to DFAT involved essentially updating and extending the WALRAS model to cover additional countries and commodities of interest to Australia and her Pacific Rim trading partners. In this sense, the project was to be a direct extension of the work previously conducted by the Growth Studies Division of the OECD (which in turn builds on the earlier trade modelling efforts of others, especially John Whalley). However, in the process of implementing this model, the basic structure has been reexamined, and altered in a number of places. Also, the choice of exogenous and endogenous variables in the model simulations (ie. model closure) has been further developed. Finally, computer implementation of the model has been vastly improved, making the work readily accessible to other researchers.

The adaptations of the OECD work under the SALTER project have been heavily influenced by the existing modelling traditions at the IC. In particular, what has come to be known as the "ORANI approach" to general equilibrium modelling has left its mark. This then is the second line of research upon which the SALTER model builds. Apart from the fact that it has generally been applied in a one-country context, the ORANI modelling approach shares the same theoretical foundations as the WALRAS model. However, in practice it has traditionally placed relatively more emphasis on data collection and parameter estimation. The ORANI school of modelling has also evolved a unique set of model closures to correspond to different simulation environments, especially differing periods of adjustment. This flexibility has proven particularly effective in adapting model results to address questions of direct interest to policy makers. Finally, the SALTER model has been implemented in the same mathematical format and software environment (GEMPACK) which has come to be associated with ORANI applications.

I believe that an important contribution of the SALTER modelling effort lies in the merging of these two previous bodies of work. The very demanding leap from one region modelling with ORANI, to multi-region modelling with the SALTER model was long overdue — particularly in light of Australia's strong interest in the current round of international trade negotiations — as well as the interest in economic cooperation on the Pacific Rim. By developing this model, based on a relatively current data base, at a significant level of commodity disaggregation, the Industries Commission has provided an invaluable service. Furthermore, by following the IC tradition of making the model available in a readily accessible software environment, the SALTER project has surely influenced the course of future research on international economic relations among Australia and her major trading partners.

III. Review of Model Structure--Broad Issues

A. *Model Coverage*

Leakages: One of the first questions which many CGE modellers will ask of a model is whether or not it satisfies Walras' Law. This is an indirect way of ensuring that all payments in the model are recirculated as expenditures, ie., that there are no leakages. If this is the case, then Walras' Law states that one of the model's equations is redundant. A numeraire price (a price index) may then be chosen, and the model is solved for price levels *relative to* the numeraire. In the SALTER model behaviour in the rest of the world is summarised with a set of excess supply/demand elasticities. That is, production and consumption decisions are not modelled and there is no explicit circulation of factor payments back through consumption. This means that, in general, Walras' Law will not apply.

A further leakage in the model derives from the treatment of capital flows among countries. These flows are not currently modelled, which means that the world as a whole is not required to be "on its budget constraint". This point is not unrelated to the absence of any explicit treatment of the rest of the world in the SALTER model. Implicitly it is assumed that capital account transactions, of an amount sufficient to offset excess demand in the eight other regions, are forthcoming from this residual region.

The final leakage in this model stems from the fact that there are no real resources consumed in the transportation of goods from one region to another. This is not uncommon in trade models. However, in the case of this particular model, where cif/fob margins are explicitly introduced, international transport activity amounts to unaccountable value-added.

The presence of leakages in economic models is very common. For example, the ORANI model of the Australian economy does not explicitly treat economic activity in the rest of the world. Thus one might justifiably ask whether measures to completely close the

SALTER model are justified. I believe they are. First, by closing the system we obtain a very powerful consistency check on the entire model. If any of the individual equations in the model are misspecified, or if any revenues fail to be properly distributed, Walras' Law will be violated. Depending on the nature of the infraction, there will be either an excess demand for, or an excess supply of the good whose market clearing condition has been omitted. In my own work this has been a valuable means of identifying the presence of errors in the model's logic or structure. A second reason for closing the model is that the rest of the world has a limited capacity for absorbing surplus production, or supplying added capital. Until this is recognised we are not assured of the model's general equilibrium solution being truly a global equilibrium.

A Suggested Procedure for Closing the Model: There are a number of different possible approaches to closing the SALTER model. Here, I will recommend one which is designed to accomplish this objective with a minimum of added data and effort. (A prefered approach would involve treating the rest of the world in the same way as the other regions in the model.) The first step involves introducing a production possibilities frontier (PPF) designed to capture the responsiveness of supplies (net of intermediate usage) from the rest of the world. Given the lack of an input-output table for this residual region it seems sensible to summarise technology in as parsimonious a manner as possible. A constant elasticity of transformation (CET) PPF may be calibrated from a vector of net supplies for this region.

Perturbation of the CET parameter will permit a straight forward means of examining the sensitivity of key model results to supply response in the rest of the world. If this proves to be critical to the study's conclusions, then more effort may be invested in the specification of technology in the rest of the world.

The second step in closing the SALTER model involves specifying final demand. Lacking data to support the disaggregation of government and private household demands, I would recommend summarising both the final demands in the rest of the world as the outcome of an aggregate utility maximisation exercise. First the allocation between savings and consumption must be made, then consumption goods would be determined by the linear expenditure system (LES), as in other regions. The composition of investment purchases is more likely to reflect patterns elsewhere in the world, and might be based on an average of shares in other regions. Total income, investment expenditure, and broad-based consumption shares may be obtained from the World Tables, with a detailed breakdown of final demand shares relying necessarily on other sources. Once one has an estimate of investment, consumption demands and net trade, net supplies of each commodity from the PPF may be obtained.

Having specified the demand for savings in the rest of the world, we must squarely confront the need for global savings to equal global investment. It is no longer possible to abstract from the question of where surplus domestic savings goes, or from whence foreign savings comes. This problem can be handled in an analogous manner to that of bilateral merchandise trade flows. Savers in each region purchase a portfolio of investment goods in each of the nine regions. Initial shares would be based on a matrix of gross bilateral capital investment flows and an elasticity of substitution would then determine the potential for reallocation in light of changes in the price of investment and rates of return in the nine regions. This is of course a "poor man's" method of determining investment allocations. Its only real virtue is that it closes the model in a consistent way.

A further limitation is the lack of data on bilateral investment flows. The latter problem may be addressed by creating a synthetic good: 'international capital', which consists of a composite of domestic capital from each of the nine regions held by foreigners. Domestic savers may in turn hold 'shares' of international capital in order to satisfy gross demand for foreign capital in any given region. In this way we would only need information on the gross outflow and gross inflow of savings in each region.

The final step in 'closing' the SALTER model involves modelling the process by which international transportation services are delivered. For starters this could be accomplished by introducing an international shipping sector which draws resources from individual regions in proportion to their contribution to world shipping activity. In any case these trade activities must absorb real resources, if Walras' Law is to hold.

Having closed the model in this manner, one is free to pick a numeraire price, and exogenously set it equal to one. Furthermore, one of the market clearing conditions must be dropped. I recommend choosing a good which is consumed in all regions, and the output of which is relatively large. A redundant equation may then be added which measures excess demand in this market. Checking that this is zero, or as close to that as is justified by computational accuracy, will provide the ultimate consistency check on the SALTER model.

B. Preferences

The structure of private household preferences in the SALTER model departs slightly from the WALRAS model. In particular, savings and current consumption decisions are separable, rather than being handled simultaneously within the extended linear expenditure system. By introducing a unitary elasticity of substitution between consumption and savings, the SALTER model retains a constant marginal propensity to save.

1. Leisure as a consumption good

One unfortunate precedent set by both the ORANI and WALRAS models, and also followed by SALTER, is the failure to deal with the labour-leisure tradeoff. This tradeoff has become a standard feature of tax policy models which are concerned with the potential disincentive effects of higher marginal tax rates on wages. Since the

SALTER model uses adjustment of the marginal income tax rate as the mechanism for keeping the government deficit in line with aggregate income growth, this aspect may merit some attention.

In any case, it is inappropriate to vary labour supply in a general equilibrium model without simultaneously considering the implications for individuals' consumption of leisure. It may be that in some of the economies being modelled, wage rigidities, or other distortions, mean that there is a surplus pool of labour available. However, if this is so, then this distortion should be directly incorporated in the model.

2. Elasticities governing current consumption

LES structure: Both models (along with the ORANI model) devote a fair amount of attention to the choice of income elasticities of demand, since the LES specification permits the modeler to calibrate to a full vector of these elasticities. Yet when one considers the changes in disposable income typically arising in these comparative static simulations (less than one percent) this attention to income elasticities seems somewhat misplaced. It is consumer prices which change most dramatically. This is particularly true in the case of farm and food policy liberalization whereby consumer prices (in Japan for instance) may have been kept at levels many times higher than world market prices.

This points to the importance of calibrating to appropriate price elasticities of demand. In this regard the structure of preferences in the SALTER model (as well as that in most other CGE models) seems quite limiting. Like the CES functional form, the popular LES structure imposes the assumption of explicit additivity. This means that the modeler has only one degree of freedom in calibrating preferences to desired price elasticities of demand (either compensated or un- compensated). In a model with 34 commodities this amounts to having little control over the price responsiveness of consumer demand, and hence the degree to which Japanese consumers, for example, will respond to the massive price cuts anticipated following agricultural trade liberalization.

Implicit additivity: An alternative specification, which I believe is preferable, involves a weaker set of restrictions on preferences, namely those implied by implicit additivity. This concept was first proposed by Hanoch in the mid-70's but it didn't attract much attention. I believe there are three reasons for this. First of all, at the time people were fascinated with the fully flexible functional forms. The idea was to test for the validity of more specific restrictions such as implicit additivity. Since then, the limitations of the fully flexible forms for policy modelling have become more apparent. This is particularly the case in trade modelling, where utility functions are required for a number of regions, many of which do not have sufficient data for estimating all of the requisite parameters.

Due to their implicit form, the functions proposed by Hanoch are cumbersome to estimate. This is the second reason for their relative disuse. (An exception is the work by Vincent, Powell, and others at the IC/IMPACT. They estimated CRETH transformation frontiers for Australian agriculture.) However, it turns out that the implicitly additive functional forms can lend themselves quite nicely to calibration, particularly at the level of generality required for a model such as SALTER. In place of the one "Frisch parameter" - or elasticity of substitution in consumption, there are now N substitution parameters which in turn permit the researcher to calibrate preferences in a manner which replicates both the full vector of income elasticities and a vector of N own-price elasticities of demand.

There are a couple of papers which develop this theme. The piece coauthored by Hertel, Peterson, Preckel, Tsigas, and Surry lays out the basic approach using the Constant Difference Elasticity (CDE) minimum expenditure function to represent preferences (as well as multiproduct technology) in a CGE trade model. The piece by Hertel, Peterson and Tsigas shows how this can be productively employed to exploit existing partial equilibrium trade model data bases in calibrating CGE trade models. We have also automated the calibration exercise. It is now available in spreadsheet format.

The third reason why I believe the CDE functional form has been relatively neglected, is due to the perceived complexity of working with an implicit function in a CGE model. In the context of a nonlinear model, solved "in the levels" a side-routine is needed to evaluate minimum expenditures at each iteration of the model (see the first piece mentioned above for more details). However, the GEMPACK approach to model implementation requires no such additional routines. Because the equations are linearised, the implicit functions are no different from any other type of expenditure functions. (The piece by Hertel, Horridge and Pearson outlines the implementation of a simple CDE based trade model using GEMPACK.)

Nesting of preferences: Another feature of the SALTER model's current specification of preferences involves the manner in which commodities are nested. The IC report recognizes the pitfalls of employing the LES (explicitly additive) restrictions at a disaggregate level, yet in the end this is precisely what is done. This means that rice and wheat share the same general substitution effect as that determining substitubility between (eg.) rice and textiles. This does not seem very plausible, and could easily be overcome by nesting some of the more disaggregated commodities. Thus, for example, food products could be combined in a CES nest prior to entering the LES system as a composite good.

At stake is the question of how the economic incidence of dramatic price shocks to some disaggregate commodities will be spread around the economy. The assumption of a commodity shared general substitution effect means that, (holding utility constant) a dramatic increase in the price of meat will have a comparable effect on the demand for all other products. That is, the demand- side effect of this price hike will be spread quite widely across the economy.

In contrast, if one recognizes that meat and dairy products are relatively closer substitutes, then the increase in the price of meats will (utility constant) do relatively more to stimulate the demand for dairy (and other food products generally). The demand for nonfood products will only be affected insofar as the cost of the composite food commodity increases. This means that the demand-side incidence effects will be more sharply concentrated within the food sector. In sum, I believe that further nesting of preferences would improve the empirical validity of the SALTER model. While this involves the choice of additional parameter values, such a step seems unavoidable.

C. Technology

Once again, the SALTER model structure follows the WALRAS model, and most other CGE models, quite closely in nesting value-added and domestic/imported intermediate goods. The absence of substitution possibilities among composite intermediate inputs, and between value-added and intermediate inputs is a tradition which has been held over from input-output analysis. It has proved to be remarkably resilient in the face of empirical evidence to the contrary. With the exception of a few models, most notably those attempting to deal with the implications of higher energy prices, CGE models invariably make this assumption. At one point it had a certain computational justification, since it enabled the modeler to collapse the entire equilibrium problem down into one of solving a set of excess demand equations for the primary factors of production. However, given the current state of computational capabilities, this property is no longer exploited. There seems to be no good justification for adopting the fixed coefficient assumption across-the-board.

Given the two experiments considered in the IC report, namely an energy price shock and agricultural trade liberalization, the need for rethinking this aspect of the model structure seems to be particularly urgent. Experience from the seventies suggests that industry and services are very capable of altering the physical proportions between energy inputs and their outputs. Thus the assumption of fixed proportions in production will surely overstate the inflationary consequences of an oil price shock, as well as the consequences for individual countries' balance of trade.

An improved specification would create a special CES nest which could be calibrated to reproduce estimates of the derived demand elasticity for energy, by industry. A lower level nest might then combine various energy types (eg. the electricity/ gas composite with petroleum and coal) to capture the potential for interfuel substitution. (As an aside, this same approach could be applied to the private household. The CDE preference structure could be calibrated to a price elasticity of demand for aggregate energy, which could then be treated as a composite commodity which again embodies interfuel substitution. See Truong (1987) for a treatment of interfuel substitution in the ORANI framework.

However, it should be pointed out that these price linkages in the model will be somewhat confused by the fact that oil and gas mining are combined in a single composite, with coal treated separately, while petroleum and coal products are aggregated, with gas (and electricity) treated distinctly. Thus the linkages from extraction to consumption are not preserved. This would limit the potential for capturing the interfuel competition in a meaningful way. For this reason some additional "strategic disaggregation" may be required if this type of experiment is to be pursued in the future.

D. Behavioural Assumptions

The assumption of perfect competition employed in the SALTER model remains the predominant behavioural postulate in CGE models. Many of those models featuring departures from this paradigm are difficult to understand, and yield surprising, counterintuitive, and even inexplicable results. In short, it seems that "anything can happen." This is a disturbing state of affairs for a policy modeler who is called upon to explain results in an intuitive way to lay audiences. Perhaps this is why CGE models with imperfect competition have been slow to catch on.

However, in models of international trade with differentiated products (eg., the SALTER model), it is not clear that the perfectly competitive framework performs any better in this regard. In particular, these models are prone to very large "terms of trade effects". In short, a given country can induce a very large revaluation of its resource endowments, relative to those of its trading partner, by imposing trade taxes. This indirect exercise of market power is enabled by the coexistence of differentiated products with price taking behaviour on the part of individual firms. In short, if market power exists, and firms do not exploit it, then there is considerable scope for commercial policy. The only way around this problem is to arbitrarily pick very large values for the elasticity of substitution among differentiated products — in effect blunting the degree of differentiation — in order to keep the terms of trade effects of commercial policy from dominating the more familiar efficiency effects.

Introducing imperfect competition into such a model is a very natural step to make, once products are differentiated. Indeed, given the efforts made by individual firms to differentiate their products, it is hard to believe that they do not subsequently exploit it by marking up their price over marginal cost. The introduction of imperfect competition into these models also eliminates the extraordinary potential for commercial policy to improve a country's terms of trade, since in the initial equilibrium firms are already exploiting this market power. As a consequence, the need to specify arbitrarily large elasticities of substitution among product varieties is also eliminated. Further, the addition of a well-defined model of imperfect competition can also help to provide some additional criteria for choosing the appropriate elasticities of substitution. They may now be related either to optimal markups, or, in the case of unrestricted entry, the share of fixed costs in total costs.

A detailed discussion of the changes to SALTER which would be required to introduce an appropriate form of imperfect competition has been appended to this review. It would probably be wise to begin with a somewhat more aggregated version of the model, producing a prototype with imperfect competition in place. This would then guide the alterations of the full model.

E. Factor Mobility

The factor mobility assumptions in SALTER are as follows:

- Labour is perfectly mobile among sectors in both the short and the medium run.
- Capital is sector-specific in the short run and mobile across sectors in the medium run.
- Land is specific to agriculture. It isn't clear what the assumption about SR mobility is, but in the medium run it is perfectly mobile across uses within the farm sector.

These assumptions are fairly standard in much of the CGE literature. However, they differ somewhat from many of the models which have attempted to deal with the agricultural sector in some detail. Farmers are notably reluctant to leave the farm. Indeed most of the empirical evidence with which I am familiar suggests that operator labour adjusts quite slowly to price shocks — much more so than land or capital. This is not the case with hired labour. However, in the short run one might argue that even farm labourers would have trouble moving into entirely different sectors of the economy. Thus a short run assumption of labour immobility out of agriculture, but free movement across farm activities may be most reasonable.

The WALRAS model uses a medium run assumption that both capital and labour are only imperfectly mobile out of farming. However, they are perfectly mobile among the two activities in the farm sector. With average depreciation rates of 13%/year on farm machinery, it is unclear to me why the farm sector cannot adjust its capital stock over the medium run. Farmers are well known for depreciating their structures and equipment during hard times and building them up in good times. However, some sort of imperfect mobility in the labour force over the medium run would seem to make sense for many of the economies being modelled here.

While the SALTER model errs in the direction of too much intersectoral mobility for labour, I believe the opposite may be true in the case of land. This is particularly true in the more densely populated economies being modelled, especially Japan. A very large proportion of that economy's farmland is readily accessible to the urban areas where there is an enormous pent-up demand for land. It is hard to believe that this demand wouldn't provide a floor below which land values would not fall.

Of course in many cases it is a favourable tax treatment of this land which is keeping it in agricultural uses, and the addition of this feature to the model would be necessary to do justice to the farm/nonfarm land market. In any case adding this dimension to the model would likely change the perception about the degree to which returns to farm assets could possibly fall, following agricultural trade liberalization.

A final point has to do with the mobility of agricultural land within the farm sector — but across uses. It is certainly the case that much of the land which is grazed by livestock in the U.S. or Australia, for example, is not appropriate for cultivation. Similarly, climatic and soil variations prevent a full mobility of land among alternative crops. Indeed, if one looks at the evidence on acreage supply elasticities in the U.S., it seems that even in the long run, the potential for land mobility across crops is limited. This in turn serves to constrain the supply response of individual crops within the sector. Hertel and Tsigas have accordingly used a CET function to determine the allocation of land among agricultural uses in their CGE model of the U.S. It would also be possible to calibrate a CDE revenue function, such that the model replicates a prespecified vector of acreage supply elasticities for individual farm products.

F. Model Closure

In general, the consideration (and institutional knowledge) which has been brought to bear on the problem of model closure represents a significant improvement over the WALRAS model. No doubt this reflects the importance of such decisions in past IC modelling efforts. However, it seems that the authors of this report box themselves in excessively by forcing all model closure decisions to fall under the heading of either short-, medium-, or longrun closures. It may be desirable to consider some of these closure decisions independently. They might even need to be varied across regions.

By way of example, consider the "short run" assumption of a perfectly elastic supply of labour, provided at an exogenous real wage. This may well be applicable in some economies, at some points in time. However, the short run could also be characterized by an extremely tight labour market in which no additional labour whatsoever is forthcoming. Surely the first assumption is not appropriate for the Japanese economy, for example.

G. Treatment of Policy Interventions

Having constructed the basic model, it is clear that the architects of SALTER are beginning to turn increased attention to the treatment of policy interventions. This is particularly important in those cases where trade liberalization is only partial. Consider the case of Japanese agricultural trade liberalization examined in the report. Table 5.4 shows the subsequent increases in exports on the part of other regions. These are quite similar across all regions with non-zero trade shares in the Japanese market. (Although, as the authors point out, the countries for which this increase is a large share of domestic production — such as Australia — the subsequent movement up the supply function tends to lessen the gains.)

But what if the price hike following the shift in demand for Japanese imports were not conveyed to domestic producers? This is more representative of the EC's farm policies, whereby the increased price simply reduces the variable levy which effectively insulates producers from the world market. This would cause a much more rapid rise in the price of EC products, subsequently inducing a significant shift towards those products supplied by countries which do not insulate producers (or consumers). In short, the way in which individual policies are modelled can make a great deal of difference in the results from such a model. Similar examples abound, and attention to the treatment of policies in the model will need to be directed by the particular application at hand. In general, the range of generic instruments considered should be extended to include fixed price schemes such as that discussed above, and fixed quantity schemes such as import and export quotas (which will encompass the popular "voluntary" export restraints).

IV. Data Base — General Comments

The work with the trade data is one of the most important contributions of the SALTER modelling effort. I think there are three important principles in this type of work. It appears that all of them have been followed here.

The first principle is: "don't be afraid to update the data base". If the model structure is adequate for simulation purposes, then it must provide some guidelines for updating the data on the basis of that information which is available for the current period. One of the mistakes of the WALRAS efforts was restricting themselves to an historical period — 10 years out of date — for which input-output tables were available. In fact, the input-output relationships change very slowly. Consequently, it is much more important to have current levels of policy intervention and trade flows than it is to have an absolutely current IO table. Thus I firmly believe that the IC pursued the correct strategy in developing an updated, 1988 data base.

The second principle in constructing a trade data base is to begin with the data which will matter most for simulation purposes. In a trade model, this is the data describing the bilateral trade flows. Since this is only available on an exhaustive basis from the UN, and since that data source is fraught with reporting problems, the task is not an easy one. It seems to me that the approach taken here — namely applying estimated reporting biases and then RASing the data is the best one can do.

The third principle is that these procedures should be well-documented and automated so that it is easy to incorporate new information, or even move to a new base year. The IC report provides good documentation. I hope the automation aspect has also been pursued. If not, it should be done as soon as possible. There is no reason why modelling exercises such as this should be tied to antique base years.

In sum, the data base (and the rather extensive discussion of parameter selection) represents a strong point of the SALTER project's final product. The authors of this work should also be aware of parallel efforts underway in Canada, under the direction of Randall Wigle. Perhaps at some point the two methodologies may be merged.

V. Overall Assessment

The final task of this review was to assess whether or not the Industries Commission has met the terms of reference for this project, as laid out in the memorandum of agreement between the IC and the Department of Foreign Affairs. Indeed, the work presented in this report indicates that these terms have been satisfied. The SALTER model data base covers the prespecified countries and regions. It also goes quite a bit beyond the requisite disaggregation of commodities/sectors. The development of a set of sound procedures for assembling and updating this data base, and the provision of a 1988 benchmark equilibrium data set, takes this work considerably beyond comparable research elsewhere. Of course the current data set will surely be subject to further revisions, as individual elements are scrutinised and improved, and as additional information becomes available. Similarly the SALTER model structure will no doubt be improved over time, as it is subjected to external reviews such as this. The fact that the data framework and model have been well documented and implemented in a manner which facilitates its use by others virtually assures this sort of evolution. The scope for adaptation of the SALTER model, and application to other issues in the area of international trade is very great indeed. As such, this project is likely to generate tangible benefits for many years to come.

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APPENDIX

Notes on Introducing Product Differentiation by Firm and Monopolistic Competition into the SALTER Model.

The Problem

The practical problem motivating this note is the tendency for terms of trade effects to dominate results from the SALTER model. This is a general characteristic of Armington-based CGE models, in which products are differentiated by region of origin. Druscilla Brown has rigorously demonstrated why this is so, in her 1987 *Journal of Policy Modeling* paper. She makes the point that differentiating products in this manner makes every country a monopolist in its own product. Consequently there are gains to be had from taxing exports, or equivalently, imposing a tariff on imports — both of which result in an improvement in the country's terms of trade. Thus even small countries will have nonzero optimal tariffs. Furthermore, given the very small values typically chosen for Armington substitution parameters, these optimal tariffs are usually quite large. Brown cites a number of instances in which this problem has cropped up in the CGE trade modeling literature.

In this 1987 article, Druscilla Brown goes on to investigate how the terms of trade effects induced by a tariff vary with the elasticities of substitution: (a) between imported and domestic goods (σ_A) and (b) among imported varieties (σ_M). As σ_A approaches ∞, the magnitude of the terms of trade effect gets very large, approaching the change in the tariff itself! Conversely, as σ_M approaches ∞ the terms of trade effects vanish.

If one truly believe that: (a) products are differentiated by nation (and not e.g., by firm), and (b) no individual actors are exploiting this market power in the initial equilibrium, then it follows that individual countries will benefit from exercising their market power — hence the large optimal tariffs. However, if one disagrees with either of these assumptions, then the basis for these very high optimal tariffs is called into question, and an alternative model specification is called for. The next section outlines one such framework. Of course there are many other paradigms of imperfect competition. However, the main point is that by bestowing market power upon individual agents in the model, the incentive for countries to manipulate their terms of trade via tariffs is vastly diminished. This is documented in the paper by Brown and Stern.

A Model of Monopolistic Competition with Differentiated Products

One of the unattractive features of the Armington-type structure is its asymmetric treatment of domestic and foreign products. Often it is more relevant to think in terms of products differentiated by firm: Holdens vs. Toyotas vs. Mazdas, for example. Adopting this approach, I suggest eliminating one level of nesting from the SALTER model and simply specifying a single elasticity of substitution ($\sigma > 1$) among all differentiated products within a given composite (i). Let θ_{rs}^{ij} = the share of product s from region r purchased by entity j in region i, so $\sum_r \theta_{rs}^{ij} = 1.0$, ie. shares for any given agent sum to one. Then the (positive-valued) perceived demand elasticity facing a representative firm in r, supplying product s to entity j in i may be written as:

$$\eta_{rs}^{ij} = \sigma + (\sigma-1)\frac{\theta_{rs}^{ij}}{n_{rs}} > 1 \qquad (1)$$

This is derived from a CES function describing the demand for a given firm's product *holding constant aggregate expenditure on product s by j in i.* If firms are presumed to charge the same price across all uses (as is the case in the SALTER model), then the aggregate perceived demand elasticity is given by:

$$\eta_{rs} = \sum_i \sum_j \alpha_{rs}^{ij} \eta_{rs}^{ij}, \qquad (2)$$

where α_{rs}^{ij} is the quantity share of the supply of s from r going to entity j in region i. Note that, for most industries, domestic uses will dominate this expression (ie. the largest values of α_{rs}^{ij} will occur when i=r). Thus domestic market conditions will dominate the determination of η_{rs}, and hence the optimal markup. The latter is given by (3):

$$M_{rs} = P_{rs}/MC_{rs} = (1 - \eta_{rs}^{-1})^{-1} \qquad (3)$$

To see quite directly how a change in the tariff in region r will affect market conditions, consider the case where a given industry in r only supplies good s to final demand in r, ie. it is purely import-competing, so that θ_{rs}^{rh} describes the domestic share in consumer's purchases of s in region r. Furthermore, aggregate the rest of the world and denote this residual region R. Proportionate differentiation of (3) yields the following:

$$\hat{M}_{rs} = \frac{-(1-\sigma)\,\theta_{rs}^{rh}}{\eta_{rs}\, n_{rs}(\eta_{rs}-1)} \{(1-\sigma)\,\theta_{Rs}^{rh}\,[(\hat{P}_{rs} - \hat{P}_{Rs} + \hat{t}_{rs}^{R}] - \theta_{rs}^{rh}\,\hat{n}_{rs} - \theta_{Rs}^{rh}\,\hat{n}_{Rs}\}\ ,(4)$$

where t_{rs}^{R} is the power of the tariff on imports of s into r from R. Since we require $\sigma > 1$, the markup by domestic firms is decreasing in the number of firms, both domestically and overseas, and *increasing in the tariff.* Thus as the tariff comes down we expect (all else constant) that the markup will also fall. This simply reflects the fact that the perceived demand elasticity has increased and the market environment is now more competitive.

It remains to describe the technology of these monopolistically competitive firms, as well as the entry conditions in this industry. Together these will determine whether excess profits are dissipated by the entry of new firms, or whether they accrue to some specific factor in the sector. The entry assumption is important for two reasons. Firstly, it affects the way we interpret the benchmark equilibrium data base. In particular, are excess profits present or not? Secondly, adding free entry to the above model amounts to adding an additional equation (zero profits) and an added variable (n_{rs}) to the model for each sector in each region.

No Entry

Consider first the no entry case in which the benchmark data set reflects an equilibrium with excess profits in a given sector s. How might one go about calibrating this revised model to the existing data base? First, note that the returns to fixed factors in the sector may be written as:

$$RENTS_{rs} = n_{rs}(P_{rs}q_{rs} - VC_{rs}) = (P_{rs} - MC_{rs})\, n_{rs}q_{rs} = (P - MC_{rs})Q_{rs}\,, \quad (5)$$

where q_{rs} is output per firm, n_{rs} is the number of firms and MC_{rs} is the marginal cost of production in the sector, which is assumed invariant to scale. Dividing by industry revenue ($P_{rs}\ Q_{rs}$), gives:

$$\beta^{F}_{rs} = RENTS_{rs}/P_{rs}Q_{rs} = (1 - M^{-1}_{rs}) = 1 - [(1 - \eta^{-1}_{rs})^{-1}]^{-1} = \eta^{-1}_{rs} < 1. \quad (6)$$

Thus if we can estimate the share of rents in total receipts, we can obtain an estimate of the aggregate perceived demand elasticity facing a representative firm producing product s in region r. (Provided we believe this is the correct model.)

If σ is the same across all regions and uses, then equation (2) collapses to:

$$\eta_{rs} = \sigma - (\sigma - 1)\, \bar{\theta}_{rs}/n_{rs}\ , \quad (7)$$

when $\bar{\theta}_{rs}$ is the share-weighted mean of country r's share in international markets for s. For example, if an industry only produces for the consumer goods domestic market and if it has 80% of the market — shared among four firms, then $(\bar{\theta}_{rs}/n_{rs}) = (0.80/4) = 0.20$. Thus given estimates of β^F_{rs} and $(\bar{\theta}_{rs}/n_{rs})$ we can infer a value of σ. Finally, note that as the number of firms (n_{rs}) increase, or as θ_{rs} decreases, such that the individual firm in question has a relatively small market share, then $\eta_{rs} \cong \sigma$ and we have the result that $(\beta^F_{rs})^{-1} \cong \sigma$.

Once β^F_{rs} has been determined, it is necessary to decide what part of "imputed costs" in the perfectly competitive data base will be cut at the expense of rents. Since rental type income is typically part of the return to capital in the benchmark data set, there is a reasonable upper bound: $\beta^F_{rs} \leq \beta^K_{rs}$, where β^K_{rs} is the share of all capital in total costs in the perfectly competitive data base. This in turn circumscribes the potential values of σ. For example, if capital payments are 20% of sectoral receipts, then we must choose values of σ which are in excess of five.

Finally, it is necessary to assign ownership of these specific assets. This will likely not be a problem in the SALTER model, since both competitive capital returns and pure rents will accrue to the same private household.

Simulation of perturbations to the no entry equilibrium requires only a few model modifications.

(A) Zero Profit Conditions are dropped, and replaced by the following pricing condition [a linearization of (3)]:

$$\hat{P}_{rs} = \hat{MC}_{rs} + \hat{M}_{rs} = \sum_j \beta^j_{rs} M_{rs} \hat{W}^j_{rs} + \hat{M}_{rs} \ , \qquad (8)$$

where β^j_{rs} = the share of variable input j in *total receipts* from s produced in region r, $M_{rs} = P_{rs}/MC_{rs}$ = the optimal markup and $\hat{W}^j_{rs}$ is the proportional change in variable input prices facing this representative firm. Note also that $\sum_j \beta^j_{rs} M_{rs} = M_{rs} (M^{-1}_{rs}) = 1$.

(B) Add an equation describing how the optimal markup varies as a function of relative prices charged by firms and the tariffs. First note that the proportional change in the firm's aggregated perceived demand elasticity is just the share-weighted sum of all the individual proportional changes:

$$\hat{\eta}_{rs} = \sum_i \sum_j \gamma^{ij}_{rs} \left[\hat{\eta}^{ij}_{rs} + \hat{\alpha}^{ij}_{rs} \right] \ . \qquad (9)$$

where $\gamma^{ij}_{rs} = \alpha^{ij}_{rs} \eta^{ij}_{rs}/\eta_{rs}$ = the contribution of the j^{th} activity in region i to the aggregated perceived demand elasticity for s, as supplied by r. Next define the differential tariff t^l_{rs} which applies to sales of commodity s from l to r. Then the general expression for η^{ij}_{rs}, *in the absence of entry*, is as follows:

$$\hat{\eta}^{ij}_{rs} = \frac{(1-\sigma)^2 \theta^{ij}_{rs}}{\eta^{ij}_{rs} n_{rs}} \left\{ \hat{P}_{rs} - \sum_l \theta^{ij}_{ls} \left(\hat{P}_{ls} + \hat{t}^l_{rs}\right) \right\} \ , \qquad (10)$$

where $t^l_{rs} \equiv 1$ when l = r, so that $\hat{t}^r_{rs} = 0$ (no tariff in domestic production).

Finally, express the proportional change in the optimal markup as a function of $\hat{\eta}_{rs}$:

$$\hat{M}_{rs} = - \hat{\eta}_{rs}/(\eta_{rs} - 1) \quad . \qquad (11)$$

Thus substitution of (10) into (9) and the resulting expression into (11) gives the desired equation which may be incorporated into the model.

(C) Modify the parameters in the commodity market clearing conditions to reflect both the diminished usage and smaller initial supply of mobile capital.

(D) Modify the computation of income to include returns to fixed factors.

Adding Entry

The addition of entry as a potential factor in the initial equilibrium, and in perturbations from it, changes several things.

(E) Reintroduce zero profits, taking into account the fact that longer production runs perform, will lower average total cost (ATC_{rs}) which is equated to price as follows:

$$\hat{P}_{rs} = \hat{ATC}_{rs} = \sum_{j} \beta^{j}_{rs} \hat{W}^{j}_{rs} - \beta^{F}_{rs} \hat{q}_{rs} \qquad (12)$$

where $\hat{q}_{rs}$ is the proportional change in output per firm and the summation is now over *all* inputs j (including the fixed capital input — which presumably has the same rental rate as the variable component).

(B') Since the number of firms now changes in order to enforce zero profits, the equation describing the individual firm's perceived demand elasticity must also be altered to reflect this fact:

$$\hat{\eta}^{ij}_{rs} = \frac{(1-\sigma)\,\theta^{ij}_{rs}}{\eta^{ij}_{rs} n_{rs}} \left\{ (1-\sigma)\,[\hat{P}_{rs} - \sum_{l} \theta^{ij}_{ls}\,(\hat{P}_{ls} + \hat{t}^{l}_{rs})] - \sum_{l} \theta^{ij}_{ls}\,\hat{n}_{ls} \right\} \quad (10')$$

(C') Replace $\hat{Q}_{rs} = \hat{q}_{rs}$ in the commodity marketing clearing conditions with $\hat{Q}_{rs} = (\hat{n}_{rs} + \hat{q}_{rs})$, and add $\lambda^{F}_{rs}\,\hat{n}_{rs}$ into the demand for capital equation, where λ^{F}_{rs} = fixed capital's share in total capital demand. This captures the fact that new entrants each require fixed capital. Alternatively, the exit of firms frees up fixed capital.

(D') Income is now computed by adding in the household's earnings on *all* capital at the competitive rate of return.

Calibration to the entry assumption is virtually identical to before, only now $\beta^{F}_{rs} = (W^{K}_{rs}\,K^{F}_{rs}) \,/\, P_{rs}\,q_{rs} = \eta^{-1}_{rs} < (W^{K}_{rs}\,K_{rs}) \,/\, P_{rs}\,q_{rs}$ where K^{F}_{rs} is the quantity of fixed capital required, per firm and K_{rs} is total capital usage per firm.

Variations on this Theme and Application to the SALTER Model

The declining average cost/monopolistic competition paradigm outlined above will not be appropriate to all industries. Consider agriculture, for example. At the farm firm level, products are rarely differentiated. Yet national products are not perfectly homogenous due to differences in climatic and agronomic characteristics as well as differences in health standards (and differing degrees of political influence!) Hence the empirical popularity of the Armington specification in agriculture. If we accept the national product differentiation paradigm in the case of agriculture, the question remains: are individual agents exploiting this market power in initial equilibrium? If seems rather clear that in many instances they are. This is a major objective of the Australian marketing boards, as well as their counterparts around the world. If these agents are already computing an "optimal" markup, then we can once again employ the above model only this time it is applied to export marketing industries. (In the case of statutory authorities the no entry assumption is most appropriate. However, in the case of U.S. grains exports, this marketing function is handled by a handful of private firms. Perhaps free entry should be permitted in the long run?)

Where do these marketing agents presently appear in the data base? One easy solution would be to take the international transportation "margins" (in the case of agricultural exports) and assign these activities to marketing agents which in turn set a price for (e.g.) Australian wheat, based on the aggregate perceived demand elasticity of export demand. By permitting β^F_{rs} to take on any value between zero and one, you could match any value of σ, given $(\bar{\theta}_{rs}/n_{rs})$.

Finally, note that there are many other paradigms built around the notion of product differentiation. One possibility is to introduce oligopolistic interactions (eg., Cournot behavior) into markets when the number of films is relatively small. Also, it is not implausible to leave the perfectly competitive/Armington assumption in place for some industries, Every imperfectly competitive agent you introduce will diminish the terms of trade impact of any given tariff, so that leaving the conventional specification in some sectors — provided this can be justified, will not jeopardize the overall results.