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John Whalley

This paper contains preliminary findings from research work still in progress and should not be quoted without prior approval of the author.

DEPARTMENT OF ECONOMICS
THE UNIVERSITY OF WESTERN ONTARIO
LONDON, CANADA
N6A 5C2
WHAT HAVE WE LEARNED FROM GENERAL EQUILIBRIUM

TAX POLICY MODELS?

John Whalley
Department of Economics
University of Western Ontario
London, CANADA

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I. INTRODUCTION

The brief that I was given for this paper was to review experience with recent general equilibrium tax policy models, reflecting upon what we have learned, and how these models can best be used in the policy process. The impression I have is that people in both the policy and academic communities are impressed by the technical sophistication of these models, since they capture interactions among many different markets in the economy and a rich array of preference and technology parameters. But there is a degree of skepticism in both communities when it actually comes to using their results to formulate policy.

It is widely believed that, even if structurally complex, these models remain overly simple in their treatment of a variety of features, such as time, market structure, foreign trade, public expenditures, and especially the intricacies of the taxes being studied. Also, the specifications used are not tested in any meaningful sense, and model simulations are based on imperfect and, at times, grossly unreliable data. It might therefore seem tempting for those engaged in policy making to dismiss results from general equilibrium tax policy models as both naive and too remote from the practicalities of day-to-day policy making to be particularly useful.

I will argue in this paper that this view of recent modelling experience is a little too pessimistic. While it may be true that there have been models built at too great a remove from the day-to-day operation of policy making, this is by no means true of them all. Moreover, while the results generated by them are perhaps still largely in the professional journals rather than in the folklore of the policy community, these models have already contributed a surprisingly large amount which is of direct relevance to tax policy design.
Their major contribution lies in providing broad-ranging insights, many of which challenge existing perceptions as to the ways in which tax policies impact on the economy, rather than in providing precise numbers as to the particular effects that would follow if this or that tax policy change were to be enacted. These insights are fresh and novel, and on occasions provide wholly different perspectives on tax policy compared to conventional wisdom.

Also, I will argue that one has to evaluate experience with these models relative to the other options available to policy makers. From my experience of the tax policy making process, it is the effects of taxes on resource allocation and income distribution that usually dominate debates on tax structure. But when it actually comes to making decisions, time horizons are short, reliable data are frequently unavailable, and decisions are as often based on the hunches and firmly-held beliefs of the small number of people intimately involved in advising political decision makers as they are on the results of analytically-based modelling. If policy makers want input from economywide numerical models that deal with both of these key dimensions of tax effects and are based on a solid theoretical framework, there really are few alternatives to using some form of numerical general equilibrium model.

Judged in this light, I will argue that the general equilibrium tax models of recent years have provided much of value for the policy making community, that will be enduring in the longer term. Many of the most important contributions of these models are in the form of background work that contributes to a general climate of opinion in which policy decisions are made. These models thus need to be seen in a quite different light compared to the macro forecasting models of the 1960s. They are best thought of as
attempts to use numerical versions of existing theoretical models with specific functional forms and parameter values. This added structure is then used to investigate model behaviour under alternative policy changes. They are not forecasting tools built to give an accurate picture of the future time path of actual economies, but are instead a form of theory with numbers which generates insights rather than precise forecasts.

The paper begins by summarizing some of the recent models, emphasizing the insights which their use has generated. In so doing it delves more deeply into a smaller number of tax models than summarized in a related and recent survey paper covering similar issues (Shoven and Whalley (1984)). I have also consciously tried to concentrate on current modelling work.

There are wide-ranging implications of model results with implications for how efficiency and distributional considerations should enter tax design, and more specific insights related to concrete policy proposals. These typically involve particular policy proposals, where prior to the proposal being evaluated by the model there was either no guidance offered in the literature, or a prior belief based on little or no previous analytic work. Several examples are given in the text. Instances are quoted where results from general equilibrium tax models have challenged prevailing views, or provided strongly intuitive insights when none were previously available.

The paper concludes by raising some issues of model design. All uses of these models are to some degree dependent upon model structure and the elasticity configurations used, and their robustness, both to model structure and to elasticities, needs careful evaluation. The large degree of subjective judgement which goes into building general equilibrium tax models, or indeed any other type of large-scale model, is emphasized. Also in contrast to the
1970s, an increasingly issue-specific focus is appearing in more recent work in this area in contrast to earlier general-purpose modelling, some of which had an air of model building for its own sake. The issue-specific focus of more recent modelling I view as a constructive development; but it has its own difficulties, not the least of which is the proliferation of large numbers of closely related small-scale issue-specific models.

II. APPLIED GENERAL EQUILIBRIUM POLICY ANALYSIS

Most existing general equilibrium tax policy models are based on the well-known Arrow-Debreu (1954) model which, since the 1950s, has become the centrepiece of modern economics. This model appears in the literature in many different forms. At an abstract level it can be found in its original formal statement in Arrow and Debreu. It appears in diagrammatic form in the well-known two sector treatment associated with Johnson (1958); and Meade (1955). It is also to be found in the formalizations of market-clearing equilibrium which are now popular in modern macro economics (see Sargent (1976)).

The structure of the basic model is both simple and easy to understand. Consumers have preferences and maximize utility subject to their budget constraints. This leads to consumer demand functions, which, when aggregated across households, yield market demand functions. The economy also has a specification of technological possibilities, through which commodities can be used to produce other commodities. Economy-wide endowments are owned by consumers, and when sold yield income which finances demands. Endowments and technology jointly define the production possibilities set for the economy, and producers maximize profits, which determines their production decisions. An equilibrium occurs when relative commodity prices are such that all markets clear simultaneously. In equilibrium, market demands (consumer demands plus
business demands for inputs) equal market supplies (endowments plus production), and no above-normal profits are made by any producer.

Over the years, this basic model has been applied and reapplied to tax analysis. In the 1950s, tax incidence questions were analyzed theoretically by Johnson (1958) and others using this model. In the 1960s, functional incidence questions and the efficiency effects of taxes were investigated numerically by Harberger (1962) using various approximation devices. In the early 1970s, this same model was used by Shoven and Whalley (1972) and others to analyze the combined efficiency and distributional effects of a variety of taxes using general equilibrium computational techniques. This work subsequently lead to larger-scale applied general equilibrium tax models based on representative data sets and parameter values for particular economies, such as Piggott and Whalley's (1977, 1985) model of the U.K., the Ballard, Fullerton, Shoven, and Whalley (1985) model of the U.S., Kehoe and Serra-Puche's (1983) model of Mexico, Keller's (1980) model of Holland, Piggott's (1980) model of Australia, Kehoe et al.'s (1986) model of Spain, and others.

Clearly, in building such models there are many elements of model design to be dealt with, even before one confronts the issue of how taxes are to be analyzed using such an approach. The dimensionality of the model in terms of goods and numbers of households needs to be decided upon. The treatment of time, foreign trade and a series of other issues has to be resolved. Functional forms must be selected, and parameter values representative of the economy being studied must be chosen.

Functional forms are typically restricted to the family of "convenient" forms (Cobb-Douglas, CES, LES), in part to simplify computation, and static or
simple dynamic models are used. Taxes typically enter this approach through ad valorem distortions between buyers' and sellers' prices, which affect the allocation of resources and redistribute income.

In conducting policy analysis using the applied general equilibrium approach, the procedure that has come to be widely used is counterfactual equilibrium analysis (see Mansur and Whalley (1984)). This approach first involves calibration of a general equilibrium model to a data observation deemed representative of an original equilibrium. This is based on the strong assumption that the economy in question is in an equilibrium situation in the presence of the tax policies which currently apply. Policy changes are then considered as counterfactual experiments, with a new equilibrium computed for each alternative policy to be analyzed. A comparison between any computed counterfactual equilibrium, and the original (or benchmark) equilibrium provides the basis for an evaluation of the consequences of the policy change. Counterfactual analysis using these techniques therefore offers a capability for analysis of the impacts of a variety of hypothetical tax alternatives.

The current widespread use of model calibration, in part, reflects the difficulties encountered in some of the larger-scale models developed in the early 1970s. At that time, the thinking was that one could simply go to the literature and extract estimates for production functions, demand functions, and other model parameters and use them directly in numerical general equilibrium models. However, it became apparent early on that if one computed an equilibrium for a model of an actual economy based solely on literature estimates, its equilibrium behaviour before any policy changes were considered would in no way correspond to information available in national accounts and
other sources indicating how the economy actually behaved during the year in question.

Because of this experience, the calibration procedures that have evolved take the requirement of replicating a micro-consistent equilibrium data set solution as an identifying restriction. This, in turn, means that applied models are typically not estimated, but only calibrated to a benchmark equilibrium data observation. Any additional parameter values required in this process, such as elasticities, are exogenously specified. Computation of equilibrium is thus only undertaken when the impacts of a hypothetical policy change are to be considered, and at this point any one of a variety of computational methods can be applied.

III. **EXTENDING THE BASIC GENERAL EQUILIBRIUM MODEL TO INCORPORATE TAXES**

The basic general equilibrium model is static, assumes a competitive market structure, and ignores risk. In its simplest form it also ignores international trade by assuming a closed economy. There is no time dimension specified for the economy to adjust from one equilibrium to another, nor is any intertemporal optimization explicitly introduced. Because of these deficiencies, in subsequently extending general equilibrium models to incorporate tax effects and in building models with a claim to be representative of actual economies, this basic structure has had to be elaborated on in a variety of ways in all the models mentioned above.

**Incorporating Taxes**

Early on, Shoven and Whalley (1972, 1973) showed how a variety of taxes can be simultaneously incorporated into the basic general equilibrium approach. These include income taxes modelled as taxes on personal incomes at progressive rates; corporate taxes modelled as taxes on inputs of capital by
industry; property taxes, also modelled as taxes on factor inputs; social security taxes modelled as payroll taxes; and sales and excise taxes, modelled as either output taxes by industry or consumption taxes by households.

Shoven and Whalley indicated that a fundamental difference in equilibrium structure that taxes introduce into the original Arrow-Debreu general equilibrium formulation arises from the endogeneity of tax revenues. Shoven and Whalley showed how the traditional N dimensional equilibrium problem becomes an N+1 dimensional problem in the with-tax case. This is because tax revenues have to be fully incorporated as part of the equilibrium structure, accruing either to the government, or to households through government redistribution. This creates a simultaneity in that until revenues are known, it is not possible to calculate household demands; but in turn, tax revenues depend upon demands. Using an N+1 dimensional extended price-revenue simplex, both a traditional Arrow-Debreu proof of the existence of a competitive equilibrium in the presence of taxes, and a constructive proof based on Scarf's algorithm are possible (see Shoven and Whalley (1973), and Shoven (1974)).

Shoven and Whalley also demonstrated how it is possible to move beyond small-dimensional illustrative examples and build computational general equilibrium models, representative of actual economies. An early example was Whalley's (1973) general equilibrium tax model of the UK, designed to analyze the effects of several tax changes occurring at the time of British entry into EEC.

Subsequently, however, the adequacy of the way various taxes are treated has become a central issue in model design. Inevitably, any attempt to capture the full complexity of modern tax systems in a single all-embracing
model will miss some of the distorting generated by taxes, and most of the
taxes analyzed raise difficulties in modelling. In the case of the corporate
tax, for instance, modern public finance treats the tax as applying to one
financing instrument available to firms, a treatment as yet not widely
followed in these models which continue largely to follow a Harberger (1962)
type treatment as a tax on the use of capital service inputs at different
rates across industries. The full variety of differences in tax treatment
across assets, financing vehicles, and sectors stressed by King and Fullerton
(1984) is not captured. Social security schemes are frequently modelled as
payroll tax and transfer schemes, without the intertemporal structure stressed
in recent literature. Marginal distortions in personal taxes in such areas as
housing, charitable giving, debt financing of asset accumulation, and others
are not well captured.

Modelling Time

To incorporate time more fully, dynamic equilibrium specifications in
which sequences of equilibria are computed have been used in a number of the
general equilibrium tax models. An important strand of this literature
initiated by Summers (1981) and taken further by Auerbach, Kotlikoff, and
Skinner (1983) and others has used an overlapping generations life cycle
structure to model numerically the intertemporal effects of taxes. Their
dynamic sequencing approach involves utility-maximizing behaviour subject to
lifetime wealth constraints. Summers' original work suggested large welfare
effects from moving from an existing income tax to a consumption tax based on
a comparison between steady states, and attracted a lot of attention when it
appeared because of the size of the results. Subsequent work by Auerbach and
Kotlikoff (1983) and Auerbach, Kotlikoff, and Skinner (1983) has, however, suggested that these effects are considerably smaller once the transition to a new balanced growth path is also included.

In related work, Ballard, Fullerton, Shoven and Whalley (1985) have also developed a tax policy model for the U.S. economy with an intertemporal structure in which savings depend upon expected rates of return facing investors. Savings reflect household intertemporal utility-maximizing behaviour, with the utility function of households defined over consumption today and expected future consumption. Consumers are infinitely lived, and in each period they maximize utility subject to current income rather than lifetime wealth constraints.

In these models, the economy is specified as having a capital stock, at an initial given point in time, which subsequently changes through time reflecting savings behaviour. A change in tax policy that stimulates consumption, such as a move from an income to a consumption tax, has the effect of instantaneously increasing savings, which increases the capital stock but decreases consumption. This reduction in consumption leads to an immediate decrease in welfare, but the higher capital stock eventually generates higher output and thus higher consumption. At some point the consumption profile under the new tax regime will cross the consumption profile associated with the original tax regime. The welfare impacts of changing from one tax regime to another can then be assessed by comparing these consumption profiles in welfare terms.

**Trade and Factor Flows**

A further area where elaborations on the basic general equilibrium model have taken place is the treatment of foreign trade, and the external sector
more broadly defined to include factor flows. This raises an important set of modelling issues for tax policy models, particularly when analyzing the effects of taxes on small open economies (see Whalley and Yeung (1984) and Hamilton and Whalley (1986b)).

In this area of modelling, a number of different approaches have been used. Trade in goods has been incorporated through a net trade function for the foreign country, with which the single country being modelled trades. This can involve a foreign offer curve, as used by Boulder, Shoven, and Whalley (1983) in their work on the U.S. Typically these net trade functions are specified in constant elasticity form, which in the simple two good case degenerates to a constant elasticity offer curve. In this case, through the trade balance restriction, the elasticity of the offer curve simultaneously implies both an elasticity for export demand and an elasticity of import supply faced by the country being modelled.

Other approaches, however, can be taken to external sector closure. One that was used recently by Hamilton and Whalley (1986b) involves explicitly modelling price-taking behaviour by using the fixed world prices to determine endogenously both zero-profit factor prices, and outputs of domestic industries using full employment conditions for domestic factors. For smaller economies, such as Canada, this form of treatment may be more appropriate than a foreign offer surface type closure.

Other modelling issues arise with the treatment of international factor flows. The traditional general equilibrium model assumes fixed endowments of factors by country, and yet tax policy towards inward and outward capital flows can be important, especially in smaller economies. In their elaborations of the basic Ballard et al. U.S. tax model, Boulder, Shoven, and Whalley (1983) have shown not only how this model can also be extended to
incorporate factor flows, but, through their results, the importance of this for the analysis of tax policies.

Modelling Risk

Another elaboration of the basic Arrow-Debreu model that has been used in the tax area involves the incorporation of risk. This is somewhat more complex than modifications to include time, but Slemrod (1983, 1985) and Galper, Lucke and Toder (1986) have taken important strides in this direction. In Slemrod's model, for instance, household behaviour towards risk is reflected in utility functions that include a constant coefficient of relative risk aversion. Prior to their decisions on consumption of commodities, households make decisions on the amount of risk they wish to bear. In turn, firms supply both risky and riskless assets, with their supply decisions reflecting relative tax costs of these financing instruments and elasticity of substitution parameters between them. As Slemrod shows, the treatment of risk can also make a substantial difference to the behaviour of general equilibrium tax models.

Market Structure

Market structure is another area that invites elaboration on the basic Arrow-Debreu model. The basic general equilibrium model uses a strong assumption of competitive pricing, but in some of the other policy areas where applied general equilibrium models have been used, it has become apparent how important these market structure assumptions are. This is most notable in the trade area, where the work of Harris (1984) has emphasized how, for small economies engaging in trade liberalization, a change in assumption from competitive behaviour to collusive pricing along with increasing returns to scale can dramatically change the welfare effects associated with changes in
trade policy. Although similar modifications in the tax policy area have not yet been made, their potential importance seems clear from the work thus far in trade.

The discussion above thus gives some idea as to how the basic Arrow-Debreu general equilibrium approach has been adapted and extended when applied to numerical general equilibrium tax policy modelling. These variations on the basic approach offer a rich modelling capability for tax policy analysts, but also a perplexing range of choices for the policy maker wishing to obtain definitive answers as to the likely impacts of any proposed policy changes. There is little doubt that the particular model variant used, along with the choice of numerical specification, can substantially affect the results that these models yield as to tax policy impacts. Anyone familiar with the way economic theory has evolved over the last 10 or 15 years will be well aware that there are many different variants of theoretical models which each give widely differing analyses of policy issues, and the proliferation of variants of the basic Arrow-Debreu model in applied work is, in part, a reflection of this. Indeed, it is clearly misplaced to think that just by building a numerical model of an actual economy one can avoid the difficulty of choosing among these variants. In analyzing particular tax policy questions, policy analysts have to be aware that, even if one is using a numerical framework in which a variety of theoretical structures can be accommodated, this does not end the difficulties of modelling since the choice of structure and method of model specification will affect the conclusions reached.
IV. Some Examples of Applied General Equilibrium Tax Models

To get a fuller picture of the approach to tax policy modelling represented by recent applied general equilibrium tax models, it may help to delve more deeply into individual models; seeing how they have been constructed, to what issues they have been applied, and what the main findings have been. In this section seven recent modelling efforts representing a variety of approaches are briefly summarized. Two (Piggott and Whalley, and Ballard et al.) are larger-scale multiple purpose models aiming to capture the major distorting effects of complete tax systems. Two (Slemrod, and Summers) are smaller-scale, more issue-specific modelling efforts focused respectively on tax issues associated with risk taking and intertemporal allocation. The final three (Goulder and Summers; Galper, Lucke and Toder, and Jorgensen and Yun) are more recent pieces indicative of the evolution of the field into new areas. Tables 1 and 2 summarize some of the main features and policy implications of results of each of these models. Since all but one of these models are of the U.S., in Appendix A some further tables are presented for a range of models for other countries.

Piggott and Whalley (1977, 1985)

Piggott and Whalley use a large-scale model developed in the mid 1970s to evaluate the distorting effects of the tax and subsidy system in the United Kingdom in operation at the time. Their model is calibrated to a 1973 data set; 1973 being a year in which major changes were made in the UK system, including the introduction of a value-added tax.

The model incorporates thirty-three industries, a similar number of commodities, and two primary factors of production, capital and labour. Government, investment, and foreign sector activity are represented through
<table>
<thead>
<tr>
<th>Model</th>
<th>Economy Studied</th>
<th>Base Year Data</th>
<th>General Purpose or Issue Specific Model</th>
<th>Dimensionality</th>
<th>Taxes Covered</th>
<th>Functional Forms</th>
<th>Main Policy Questions Analyzed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piggott, Whalley</td>
<td>U.K.</td>
<td>1973</td>
<td>General purpose</td>
<td>33 industries, 100 household groups</td>
<td>All major taxes and subsidies</td>
<td>Nested CES-LES</td>
<td>Removal of major distortions in tax-subsidy system, and specific taxes and subsidies</td>
</tr>
<tr>
<td>Ballard, Fullerton, Shoven, Whalley</td>
<td>U.S.</td>
<td>1973</td>
<td>General purpose</td>
<td>19 industries, 15 consumer goods, 12 household classes</td>
<td>All major federal, state and local taxes</td>
<td>Nested CES-fixed coefficient (production)</td>
<td>Integration of corporate and personal taxes; introduction of progressive consumption tax</td>
</tr>
<tr>
<td>Slimrod</td>
<td>U.S.</td>
<td>1977</td>
<td>Issue specific: capital income</td>
<td>9 income classes, 4 goods, 6 assets</td>
<td>Personal and corporate income taxes, property taxes</td>
<td>Cobb-Douglas (consumption)</td>
<td>Indexation of tax system</td>
</tr>
<tr>
<td>Summers</td>
<td>U.S.</td>
<td>No historical data used (rough approximation)</td>
<td>Issue specific: capital taxation</td>
<td>1 good, 1 household sector</td>
<td>Capital taxes</td>
<td>Constant elasticity with constant rate of discount (utility)</td>
<td>Replacement of capital income taxation by consumption tax</td>
</tr>
<tr>
<td>Boulder, Summers</td>
<td>U.S.</td>
<td>1973</td>
<td>Issue specific: asset prices and investment</td>
<td>5 industries, 15 consumer goods, 1 household</td>
<td>Major federal, state and local taxes</td>
<td>CES-fixed factor (production)</td>
<td>Reduction in corporate tax rate; reduction of investment tax credit</td>
</tr>
<tr>
<td>Galper, Lucke, Toder</td>
<td>U.S.</td>
<td>1983</td>
<td>Issue specific: capital stock allocation</td>
<td>3 suppliers of capital, 400 representative households</td>
<td>Statutory corporate tax, entire schedule of personal taxes</td>
<td>Unit elastic demand for capital</td>
<td>Introduction of flat tax; integration of corporate and personal taxes</td>
</tr>
<tr>
<td>Jorgensen, Tun</td>
<td>U.S.</td>
<td>1955-1980 (econometric estimation)</td>
<td>Issue specific: sales tax on capital investment goods, income tax on capital and labour services, property taxes</td>
<td>1 consumer, 3 sectors, 4 commodity capital allocation groups</td>
<td>Intertemporal logarithmic utility function with constant rate of discount, atemporal allocation based on translog indirect utility function; translog price functions with two-stage allocation process (production)</td>
<td>Introduction of tax reform measures in U.S. in 1981-82; neutralizing treatment of different assets; replacement of direct taxes on income from capital by indirect taxes on consumption</td>
<td></td>
</tr>
</tbody>
</table>

1Expanded to include micro unit data in a subsequent model extension; see Slimrod (1985).
Table 2
Policy Implications of Major Model Results

1. Piggott, Whalley

Distortionary effects of tax–subsidy system higher than conventionally assumed (6–9% of NDP); major sources of welfare loss are housing subsidies, excise taxes, capital income taxes.

2. Ballard, Fullerton, Shoven, Whalley

Integration of corporate and personal taxes yields significant welfare gains; introduction of progressive consumption tax yields gains of same order of magnitude; both policies can be Pareto-improving for income classes modelled.

3. Slemrod

Indexation of tax system leads to efficiency gains; lowest income classes slightly worse off, highest income classes substantially better off.

4. Summers

Increase in output and welfare from shift from capital taxation to consumption taxation much larger than previously thought; increase in welfare for representative consumer approximately equivalent to six years' income.

5. Goulder, Summers

Reduction of corporate income tax from 46 to 33% raises firm values significantly in all industries modelled (14 t2226%); reduction of investment tax credit by 50% reduces capital stock and productivity of capital; a combination of these policies reduces aggregate capital stock over the longer term.

6. Galper, Lucke, Toder

Introduction of flat tax rates and integration of corporate and personal taxes each lead to expansion of corporate sector in the absence of portfolio effects; inclusion of portfolio effects weakens and in some cases reverses this result.

7. Jorgensen, Yun

Tax reform of 1981–82 increased potential economic welfare by 3.5 to 4 per cent of 1980 private national wealth; neutralizing treatment of assets between corporate and non-corporate sectors leads to welfare losses, while shifting from direct taxation of income from capital to indirect consumption taxation leads to large gains.
separate "consuming agents" in the model. One hundred private sector household types are included, stratified by income, occupation and family characteristics. This detailed classification of households is incorporated to allow for an examination of tax incidence issues and distributional effects of tax policy changes using the model.

Consumer demand functions are derived from nested household CES utility functions. Elasticity values are chosen for the various nests to calibrate to literature estimates of own-price elasticities of demand for commodity groups. The same elasticity values within any nest are generally used for all households, as available literature estimates are not differentiated by household type.

Production functions in the model allow for substitution between factors according to CES value-added functions. Joint production and intermediate use of goods in production are incorporated using a fixed-coefficient structure. Literature sources are used to select a central set of production function elasticity values, around which sensitivity analysis is conducted.

Counterfactual experiments performed with the model involve cases in which the whole of the existing tax-subsidy system is removed, as well as cases in which only specific taxes are abolished or modified. Each of these counterfactual policy changes is made under substitution of yield-preserving, broadly-based taxes or subsidies which keep the size of the public sector constant in the model. This procedure is necessary, since changes in the relative size of the public and private sectors in tax models can give misleading estimates of gains or losses from tax changes, especially where the focus of the analysis is on the distorting effects of particular taxes and subsidies.
Using their model, Piggott and Whalley estimate that the UK tax-subsidy system accounted for annual welfare losses of six to nine percent of NDP in 1973, an estimate which, at the time, was higher than that conventionally used for such distortions. They find the principal sources of these losses to be capital income taxes, excise taxes, and local authority housing subsidies, which jointly account for approximately 80 percent of the distorting costs of the combined UK tax-subsidy system. Depending on how it is modelled, they also find the effects of inflation (in the absence of an unindexed tax-subsidy system) yield another significant source of distorting loss.

They also evaluate the income redistribution impacts of the tax-subsidy system. Tax-induced changes in the Gini coefficient, calculated using net-of-tax incomes, appear to be relatively modest, although the Gini coefficient is widely acknowledged to be an index which is relatively insensitive to distributional changes, especially in the tails of the income distribution. When Piggott and Whalley also account for redistribution in kind through tax and subsidy effects on relative prices, the impacts on the richest and poorest groups are more pronounced. In welfare terms, they find that a removal of all tax-subsidy policies and a replacement by a yield-preserving single rate commodity tax inflict a welfare loss on the poorest decile of households which is equivalent to around 20 percent of their income (in part due to the removal of local authority housing subsidies), while the top decile gains about the same amount (in part through the removal of the income tax). This picture is different from the conventional view of the redistributive impacts of the tax system based on incidence calculations, which are taken by many to suggest that the tax system has almost no impact on the household income distribution. ¹ Their model results also suggest that, using 1973 data, the

¹See Pechman and Okner (1974).
top 10 percent of income recipients would gain about one-half as much from an abolition of the local authority housing subsidies with replacement by a yield-preserving broadly-based sales tax, as they would from a similar yield-preserving replacement of the income tax. These results thus suggest that the UK tax-subsidy system in the 1970s incorporated more redistribution than might have been believed from earlier studies.

Piggott and Whalley also show how further redistributive objectives could have been achieved through what they term "specific egalitarianism", using price-distorting taxes and subsidies, although at an aggregate welfare cost. By using subsidies on food and substantial taxes on owner-occupied housing they find that it is possible to produce surprisingly large amounts of redistribution of "real" income, even when these changes are designed so as to raise no revenue on a net basis.

_Ballard, Fullerton, Shoven, and Whalley (1985)_

Ballard, Fullerton, Shoven and Whalley (BFSW) also use a large scale model, but of the U.S. rather than the UK economy, and have as their major focus intertemporal aspects of tax policy. They identify 19 producer-good industries in their model, and 12 consumer groups stratified by income. Their model calibration uses 1973 data. The functional forms they use are similar to those of Piggott and Whalley; CES value-added functions, fixed-coefficient intermediate technology in production, and nested CES utility functions in household consumption. Like Piggott and Whalley, their elasticity estimates are also derived from literature sources, and BFSW perform sensitivity analyses for the more important of these parameters, principally elasticities of labour supply and of saving.
BFSW focus on a dynamic equilibrium structure. They calculate a sequence of single-period static equilibria, in which saving decisions change the time profile of the economy's capital stock. Myopic expectations regarding the return on savings are assumed in order to simplify their computations, although in related work Ballard and Goulder (1985) have found that a different treatment of expectations has little effect on results.

BFSW use their model for a series of policy analyses. The first of these evaluates four plans for corporate and personal income tax integration. BFSW consider: (i) total integration of personal and corporate taxes; this eliminates corporate taxes and modifies personal taxes so as to tax total shareholder earnings, rather than just dividends; (ii) making dividends deductible from the corporate income tax base; (iii) making dividends deductible from the personal income tax base; and (iv) a dividend gross-up scheme, under which shareholder taxable income is "grossed up" by a proportion of the taxes paid by corporations, and shareholders are given a corresponding tax credit. Each plan is evaluated using different methods to preserve tax revenues: lump-sum taxes; additive scaling of marginal income tax rates; multiplicative scaling of marginal income tax rates; and a replacement value-added tax.

BFSW estimate that total integration of corporate and personal income taxes would lead to efficiency gains. Depending on the replacement tax, the present value of these gains ranges from $288 to $695 billion (1973) U.S. (where the present value of future income for the 1973 population is about $49 trillion under the present system). The dynamic gains from the other three integration plans are generally lower, but exceed $50 billion in every case.
Distributional effects vary among the four plans. A total integration plan with multiplicative scaling of marginal tax rates leads to a progressive change in real income distribution over most of the income range, with every income class being better off. Dividend deductibility from personal taxes is more advantageous to the higher income groups, while deductibility from the corporate income tax redistributes from middle and lower income groups to the highest income group. The dividend gross-up plan has close to proportional effects, with slightly greater gains accruing to the top and bottom groups.

BFSW also consider replacing the federal personal income tax with a progressive consumption tax. In this model application eight different plans are evaluated, differing in the fraction of savings treated as deductible, the fraction of dividends that are taxable, the fraction of nominal capital gains taxable at personal level, and whether the elimination of preferential treatment of housing and changes in the corporate tax are also included in the analysis.

BFSW's analysis does not involve modelling either a pure income tax or a pure consumption tax, since in its treatment of saving the U.S. tax system is already part way between these two pure forms. Their results indicate, however, that a movement toward sheltering more saving from the U.S. income tax could improve economic efficiency, even if marginal tax rate increases are necessary as a revenue-preserving measure. The present value of gains under complete savings deduction with marginal rate adjustments is around $500 to $600 billion (1973). A combined policy of tax integration and savings deductions leads to even greater gains, the present value of which they estimate as lying between $975 billion and $1.3 trillion.

BFSW also use their model, among other things, to investigate the
relationship between tax rates and government revenue, and the effects of changes in tax treatment of foreign source income. They plot the tax-rate-to-revenue relationship for a range of values of labour supply elasticities, for instance, and find that reasonable estimates of the appropriate parameters suggest that broad-based cuts in labour tax rates would not increase tax revenues.

Slemrod (1983, 1985)

In contrast to Piggott and Whalley, and BFSW, Slemrod uses a general equilibrium model to analyze US capital income taxation issues allowing for adjustments in the financial behavior of households and firms in response to tax changes. In the 1983 model version, he identifies nine household income groups, each differing in their endowments of capital and labor, their preferences for consumption goods, the marginal tax rates they face, and the after-tax riskiness of the assets they hold. This treatment is expanded to capture more household detail by using micro-unit data in the 1985 model version. He specifies production functions for food, rental housing, owner-occupied housing, and a composite corporate good. Each agent has demand functions for these goods, as well as for each of six assets: food-sector capital, rental housing, owner-occupied housing, corporate equity, taxable debt, and tax-exempt debt. The model is calibrated to a stylized United States economy for the year 1977.

A number of features distinguish Slemrod's from other general equilibrium tax models. The most important is the explicit treatment of risk. Capital owners are not affected identically by tax changes in the model
because they hold different portfolios. This is because a risk-aversion parameter enters preferences, and utility-maximizing behaviour determines behaviour towards risk, as well as commodity demands. In this treatment household tax rates are endogenous, tax-exempt bonds can be held in household portfolios, and rental and owner-occupied housing are separately distinguished. Changes in corporate financial policy are accommodated by the model through response on the supply side of financial asset markets to the different costs of issuance of financial assets, including taxes, with exogenous elasticity parameters determining these supply side effects.

Slemrod's major applications of his 1983 model focus on tax distortions associated with inflation. His model base case assumes a six per cent inflation rate, and the model is re-solved assuming no inflation. As Slemrod points out, an unindexed tax system with zero inflation will yield the same equilibrium as under an indexed system, and his results thus provide some guide as to the effects of indexing the tax system.

Indexation leads to a decline in federal tax revenue of $28.2 billion in the model, of which $27.8 billion is personal income taxes and $0.4 billion is corporate income taxes. When an equal-revenue-yield constraint is imposed (under which all personal tax rates are increased by 21.1 per cent), a substantial change in the pattern of rates of return across assets results. There is a decline in the real rate of return on riskless debt, an increase in the real return to equity, and a sharp increase in the yield on tax-exempt securities. These changes have sizable effects on portfolio holdings of households, including a notable decline in the amount of equity and owner-occupied housing held by high-income households.
With an equal-revenue-yield condition imposed, Slemrod estimates the welfare effects of indexation as positive for the five highest income groups and negative for the four lowest, with the dividing line being annual income of about $30,000 in 1977. The sum of the compensating variations is positive, indicating that indexation can be Pareto-improving. But the allocation effects are small, with a slight decrease in the amount of capital used in owner-occupied housing, primarily at the expense of rental housing. Slemrod notes that this sensitivity analysis shows that the allocation effects of indexation depend on the way the housing sector is modelled, while distributional results are also affected by the type of equal-yield adjustment used.

_Summers (1981)_

In one of the first intertemporal equilibrium tax models, Summers evaluates the welfare effects of capital income taxation using a numerical overlapping-generations life-cycle model, crudely specified to be representative of the US economy. Only one sector is assumed, and the richness of the model lies in its intertemporal specification.

One of the most important features of his model is the high interest elasticity of household savings which he generates. He argues that the commonly-used two-period formulation of savings behaviour underestimates the interest elasticity because it ignores the wealth effect associated with changes in interest rates. He argues that, for almost any plausible formulation of the life-cycle hypothesis, the implied interest elasticities of savings are likely to be much greater than conventionally thought to be the case before his work.
Summers uses his model to evaluate alternatives to existing capital income taxation, specifically taxing labor income or using a consumption tax. While consumption taxation is neutral with respect to saving rates, a tax on labor income alters the time path of savings. He also points out that since consumption taxes postpone payment of taxes relative to wage taxes, the tax rates needed to meet a given government revenue requirement will differ.

Changes in taxes are evaluated using logarithmic (Cobb-Douglas) utility and production functions in his central model variant, although sensitivity analysis is performed around alternative specifications. The elasticities of substitution in production are set alternatively at 1 and .5, with the base case share of capital set at .25. An initial capital income tax rate of .5 and a tax rate on labor income of .2 are also assumed.

Through a comparison across steady states, Summers estimates that replacing the capital income tax with a wage tax will increase income by 14 per cent, and replacing it with a consumption tax by 18 per cent. These results reflect the high interest elasticity of savings in the model, as this leads to a substantial increase in capital formation.

In welfare terms, introducing a wage tax would increase welfare by nearly 5 per cent of lifetime earnings; a consumption tax would increase welfare by approximately 12 per cent, the equivalent of nearly five years' income for the economy. Summers attributes the greater gains estimated under consumption taxes compared to wage taxes to the increased capital formation which occurs, due in part to the higher savings by households who have to pay taxes later in life.

Summers concludes from his results that the costs of capital income taxation are much higher than had previously been believed. This result he
argues is due to his model generating a higher interest elasticity of saving than assumed in preceding studies, and to his general equilibrium formulation which incorporates the effects of increased capital formation.

Goulder and Summers (1986)

In subsequent work, Goulder and Summers have formulated a tax model of the United States in which they treat investment demand explicitly, rather than assume that it is determined by savings as in Summers' earlier work. They also explicitly incorporate the adjustment costs faced under any reallocation of capital between industries in response to capital income tax changes through a quadratic adjustment cost formulation related to that used by Treadway (1969). As a result, capitalization effects of tax policies enter their analysis.

Their model includes production, household, government and foreign sectors. Five industries are specified with capital and labor entering as factor inputs according to CES value-added functions; intermediate goods enter as fixed proportions. As in the BFSW model, production goods combine according to fixed coefficients to yield 15 consumer goods.

A representative consumer is assumed on the demand side of the model, who both saves and consumes the 15 consumer goods according to fixed expenditure shares. In specifying the government sector, each of the major taxes in the United States is incorporated. The explicit incorporation of profit taxes, investment tax credits and capital gains taxes allows for detailed effects of tax policies on investment to be identified. The model is calibrated to a 1973 benchmark data set based in part on the same data used by BFSW.
Gould and Summers evaluate a number of tax policy changes, first assuming that these changes are unanticipated. They calculate equilibria for their policy experiments at one-year intervals over a 60-year period, with personal taxes being scaled to yield equal tax revenue under all simulations.

Gould and Summers conclude that the effects of tax changes under their policy simulations, while consistent with economic theory, would not have resulted from models with perfect intersectoral mobility of capital or static expectations. They also point out the importance of the distinction in their model between new and existing capital for their results.

They suggest that a reduction in the corporate tax rate from 46 to 33 per cent in all industries increases firm values by 14 to 22 per cent over base case levels. Reducing each industry's investment tax credit by 50 per cent has a less pronounced effect than reducing the corporate tax rate, as the corporate tax base includes all capital while the investment tax credit applies only to new capital. Combining a reduction in the corporate tax from 46 to 36 percent, with a 50 percent reduction in the investment tax credit leads to a slower rate of accumulation and a fall in the productivity of capital over time. This is because such a policy change favors payment of dividends over investment.

The effects of announcing tax policy changes such as a lower corporate tax rate three years before their implementation are also considered by the model. A reduction in the corporate tax rate lowers the present value of depreciation allowances per dollar of investment. When this is announced, firms invest at a more rapid rate prior to the policy change than after. An announced 50 per cent decrease in the investment tax credit leads to a very slight reduction in investment prior to the policy change, as firms take
advantage of the remaining years of higher tax credits. In the long run, investment falls to a greater degree, leading to a reduced productivity of capital and lower firm values.

Galper, Lucke, and Toder (1986)

A further recent modelling effort is by Galper, Lucke, and Toder who extend previous work on the interactions of behavior towards risk and taxes. They examine the effects of tax policy changes on the allocation of physical capital by industry in a model that incorporates firm and household portfolio choice under uncertainty. The model contains an explicit treatment of risk and uncertainty. It also differs from traditional Harberger-type general equilibrium tax models by including an optimizing equation for corporate debt-equity decision-making instead of assuming it fixed, and allows asset demands to differ among households.

The 1983 data to which their model is calibrated draw on a sample of 400 US households classified by their labor and capital income, and other tax parameters. Financial assets are supplied to households by corporations, non-corporate enterprises, and state and local governments. Households also hold capital in the form of owner-occupied housing and consumer durables.

The policy changes examined using the model include the introduction of a flat rate tax for corporate and personal income, and the full integration of corporate and personal taxes. All simulations are modelled as revenue neutral.

Galper, Lucke and Toder compare their model to a Harberger-type approach in implementing their experiments. These Harberger-type simulations are achieved by replacing the demand for risky assets in the full version of the model with a specification that equalizes risk-adjusted returns for the
representative asset holder, and fixing the corporate debt-equity ratio at its initial value.

Imposing a flat tax rate in the Harberger-type version of the model leads to a fall of 1.83 per cent in the cost of capital in the corporate sector, largely because the corporate tax rate is reduced from 46 to 18 percent. The corporate capital stock increases by 18 percent and that in other sectors contracts.

Estimates using the full version of the model (i.e., including portfolio effects) are quite different. In this version, the cost of capital to the corporate sector is affected not only by the reduction in the corporate tax rate, but also by the higher yields on corporate equity required to induce households to hold these assets (as a drop in the tax rate makes taxable bonds more attractive), and by the shift away from debt financing by corporations, given the reduced tax advantage of interest deductibility. As a result, the corporate cost of capital falls by only .07 per cent, and the corporate capital stock increases by approximately .5 per cent. Households in higher brackets now find the opportunity cost of holding housing and consumer durables has increased, and they hold less housing capital in their portfolios. The reverse is true for low-bracket households. Overall holdings of corporate equity increase, but are reduced for high-bracket households since the value of the capital gains preference drops when tax rates are reduced.

Integrating corporate and personal taxes is modelled by attributing all taxable income of corporations to shareholders, and taxing it at the shareholders' personal rate. Corporate tax preferences are passed on to individuals, reducing the share of corporate income subject to tax from 52 to 40 per cent.
The effects of integration under the Harberger version of the model are a reduction in the cost of corporate capital, and an expansion of the corporate sector by an estimated 15 per cent. In the full model version, however, these changes are approximately one-fifth as large. Since there are no longer tax advantages to corporations in issuing taxable debt, the corporate debt-equity ratio drops in the full version of the model from .446 to .034. Household sector capital declines in both versions of the model, but in the full version by one-third as much as in the Harberger version.

In general, there are great differences between the results from each of the two model specifications. The estimated effects of tax policy changes in the Harberger-type model are in some cases opposite in sign to those from the full specification of the model. Galper, Lucke and Toder conclude that the way in which financial behavior is modelled is an important determinant of the effects of tax changes on physical capital stock allocation among industries.

Jorgensen and Yun (1986)

Jorgensen and Yun present an intertemporal general equilibrium model for the United States to analyze the impact of tax policies on capital allocation. They specify 4 commodity groups, 3 sectors, and one infinitely-lived consumer with perfect foresight. Their analysis of tax issues concentrates on the provisions of U.S. tax law applicable to income from capital. Their work is distinguished by the use of econometric methods for estimating model parameters. Their estimation involves the construction of a system of accounts for the U.S. for the period 1955-1980 which includes income and expenditure accounts for the business and household sectors.
They begin their evaluation of various tax policies by examining the tax changes introduced in the U.S. during 1981 and 1982. Using an assumed rate of inflation of 6 per cent, they estimate the present value of the potential welfare gains of these tax policy revisions to be $542 billion (1980) with a lump-sum revenue adjustment, $328 billion with revenue maintained by increased taxes on labor and $295 billion with increased sales taxes. These gains are equivalent to 3.5 to 4 per cent of 1980 private national wealth. The authors emphasize that these are potential rather than actual gains, as with a single consumer in their model distributional effects cannot be evaluated.

Using the 1981-82 reform program (with a 6 per cent inflation rate assumed) as the reference case, Jorgensen and Yun evaluate the effects of further reforms. First, they estimate the welfare impacts of eliminating differences in effective tax rates between long-lived and short-lived assets. They then assess the effects of eliminating distortions due to differences in effective tax rates between the corporate and non-corporate sectors. Finally, they estimate the effects of applying consumption tax treatment to investment decisions. All experiments are evaluated under the three different revenue-equalization strategies above.

Jorgensen and Yun's simulations indicate that policies with effective tax rates of zero for all assets dominate other tax reforms. Expensing of investment expenditures and elimination of sales taxes on investment goods yields the greatest potential gains: $3.6 trillion (1980) under a lump-sum revenue adjustment, or 43 per cent of 1980 private national wealth. Under increases in labor income taxes or sales taxes, these gains are reduced to $1.9 trillion and $1.7 trillion respectively, because of offsetting distortions. The potential gains from all the experiments they perform are
positive, with the exception of the elimination of intersectoral differences in effective tax rates on assets.

V. IMPLICATIONS OF MODEL RESULTS

The previous section describes only a small subset of the general equilibrium tax models that have been built over the last ten or so years, and each of these only in extremely summarized form. All the models in this area differ substantially in structure one from another, but most yield important (and at times contradictory) indications as to the ways in which tax policies affect the economy, and the ways in which components of the tax system interact one with another.

What one draws from these results inevitably remains highly subjective. Some policymakers are convinced by some of them, others are more skeptical. Some like some of the features of any given model, but find others disturbing and often attach only limited credibility to model results. Results can often be as revealing of model structure and the key role of particular parameter values, as they are of the economy being modelled. But fresh insights emerge which are frequently provocative and stimulate debate. They can be supportive or contradictory of previously-held positions, or provide genuinely new perspectives (frequently where no received wisdom existed).

My view is that all of these contributions help the policy process, and in this section I provide some examples of policy-relevant model-generated insights. These are largely drawn from work I have been involved with, since I am most familiar with models I have worked on, but they hopefully serve to highlight how I view general equilibrium models as constructively contributing to policy debate.
Taxes and the Equity-Efficiency Trade Off

One of the more prominent themes emerging from the general equilibrium tax modelling work thus far concerns broad-ranging implications for the equity and efficiency effects of taxes.

The importance of model results has to be seen relative to the perspectives on the equity-efficiency trade off implied by existing taxes which prevailed prior to the current round of modelling. In the early 1960s, beliefs as to efficiency effects of taxes were largely based on Harberger's (1959, 1964, 1966) pioneering work. Harberger had estimated that the efficiency costs of the corporate tax were perhaps one half to three quarters of 1 percent of GNP, and in a famous paper in 1964 extended his work to a wider analysis of the efficiency effects of the whole tax system.

His conclusion was that the major efficiency costs of distorting taxes lay in the corporate tax area, and that the combined efficiency costs of all major taxes were perhaps 1 percent of GNP. At the time, many people interpreted these estimates not in the same sense of Harberger, as demonstrating welfare gains which could be realized through major tax reform, but instead as evidence that the efficiency costs of taxes were small.

Perceptions on distributional impacts of taxes have long been based on tax incidence calculations which have their origins in the work of Bowley, Stamp and Clark, and even earlier, in Gregory King. From the more recent work by Pechman and Okner (1974) on tax burdens in the United States, the picture that has emerged is that the tax system does little to redistribute income. Their analysis suggests that the progression which operates under the income tax (which is perhaps less in practice than might appear on paper) is offset
by regression elsewhere in the tax system, such as with sales and excise
taxes, and payroll taxes.

In the 1960s and 1970s, the belief among economists, in part influenced
by these studies, seems to have been that while the tax system had repeatedly
been changed in an attempt to make the tax system more redistributive, little
of it had proved to be successful. Since the efficiency costs of the
additional interventions associated with changed tax policies appeared to be
small, the direction suggested for tax policy seemed to be to continue with
attempts to make the tax system more redistributive, in the hope that
substantive redistribution would eventually be achieved. Meanwhile, social
costs through any induced misallocation of resources would not be a major
factor.

This view of the tax system has clearly been challenged by the results
emerging from the general equilibrium tax policy models. The efficiency costs
of taxes reported are generally much higher than those suggested by
Harberger's work, and especially the costs at the margin as extra revenues are
raised from existing distorting taxes. In their work in the 1970s on the UK
tax subsidy system, Piggott and Whalley suggest a range for the annual welfare
costs from distortions of between 6 and 9 percent of GNP per year. In
comparable work on the U.S., Ballard, Shoven, and Whalley (1985b) suggest an
estimate in the region of 8 percent of GNP. These models have also been used
to calculate the efficiency costs of raising additional tax revenues using
existing distorting taxes. Ballard, Shoven, and Whalley (1985a), for
instance, suggest efficiency costs for the U.S. of around 35 cents per
additional dollar of revenues collected.²
Model results have also suggested that the redistributive effects of taxes may be more significant than those portrayed by earlier incidence studies. In part, this reflects the added price endogeneity in these models, but the strong regressive assumptions implicit in the incidence treatment of such taxes as sales and excises are also important. As mentioned above, the work on the UK by Piggott and Whalley suggests that a replacement of 1973 taxes and subsidies by a yield-preserving sales tax would benefit the top 10 percent of income recipients by around 20–25 percent of their original pre-tax income, and cost the lower 10 percent of income recipients around 20–25 percent of income.

Thus, if one takes recent model results seriously, the perspective one has on the equity-efficiency choice in the design of tax policy seems to change compared to earlier received wisdom. Efficiency costs of taxes appear more important than perhaps previously thought, and the tax system appears to be redistributing income to a more substantial degree. The implication is that a change in the weight attached to tax policy concerns may be merited, shifting more towards efficiency considerations and away from redistributive issues.

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2See also Ballard (forthcoming) who evaluates the efficiency costs of redistribution through the tax system.

3Under this treatment, savings are effectively treated as free of indirect taxes; a treatment which is inconsistent with the analysis of intertemporal tax distortions emphasized in recent consumption tax literature. See also Browning (1976), Browning and Johnson (1979), and Whalley (1984).
**Intertemporal Effects of Taxes**

Another important area for results of general equilibrium tax policy models has been in the analysis of intertemporal distortions. In his work in the 1960s, Harberger suggested the intertemporal effects of taxes were small. This was largely based on the belief that the elasticity of savings with respect to the real net of tax rate of return is small, with the implication that the associated Harberger triangles were small.

This view was initially challenged in the 1970s by Feldstein's work (1978a, 1978b) which pointed out a conceptual error in Harberger's analysis; namely that a zero elasticity of savings with respect to the real net of tax rate of return does not necessarily imply a zero elasticity of intertemporal substitution in consumption. A zero savings elasticity corresponds to constant expenditure shares, which, in terms of underlying preferences defined over consumption today and consumption tomorrow, implies a substitution elasticity of approximately 1. This observation sparked a resurgence of interest in the effects of intertemporal tax distortions in the late 1970s and early 1980s.

A series of model-based papers has followed, in which the view that intertemporal effects of taxes are more important than had previously been thought has been given further emphasis. Summers' (1981) work has been especially influential in this area, and the recent results of Jorgensen and Yun (1984) seem further to emphasize the same theme. As noted above, Summers uses an equilibrium structure to analyze the effects of capital taxation distortions in a life-cycle model, concluding that the welfare costs of intertemporal tax distortions under an income tax can be as large as 10 percent of GNP.
While Summers' calculation only refers to a comparison between steady states, this strand of work has nonetheless been influential in reigniting concerns over the tax treatment of savings. This has been instrumental in fostering support for tax reform in the direction of a move toward a consumption tax, which, in turn, has injected new themes into tax reform debate in a number of countries. This is despite the fact that recent reforms in the US represent a turn towards income and not consumption taxation.

Interasset versus Intertemporal Effects of Taxes

An example of another area where important insights have emerged from recent general equilibrium tax policy models concerns the relative importance of interasset and intertemporal tax distortions. A recent paper by Hamilton and Whalley (1985), for instance, highlights how a Haig-Simons approach toward tax reform stresses the need fully to include imputed housing income in the tax base on the grounds that this is part of broadly-based income. However, when one approaches the issue of tax treatment of housing from a consumption tax point of view, one's view is that housing income is appropriately taxed, and it is the income return to non-housing assets that is inappropriately treated. Viewed from a consumption tax point of view, fully taxing income accruing to housing seems like an undesirable step.

But as Hamilton and Whalley point out, tax breaks for housing occur only if owners of housing directly consume the services yielded by the asset.

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4 When the transitional path is added in, these estimates are considerably reduced, as noted by Auerbach, Kotlikoff, and Skinner (1983). See also Davies, Hamilton, and Whalley (1986).
There is therefore both an intertemporal and an interasset distortion involved in evaluating the effects of the current tax treatment of housing.

They formulate an equilibrium model using data for Canada for 1972 with which they simulate the effects of either removing taxes on other assets, or including housing income in the tax base. They show that a move from the current tax treatment to either a pure income or pure consumption tax is welfare improving. These results are consistent with the themes emerging from the work by King and Fullerton (1984) and others on effective tax rates, which has also stressed the importance of interasset tax distortions. These results are important in that they suggest that, currently, the variance of tax treatment across assets is a more important source of distortion than conventional intertemporal tax distortions. They show a clear welfare gain to be associated with a move to a pure income tax, as well as a consumption tax, even though intertemporally an income tax intensifies tax distortions.

**Border Tax Adjustments**

An example of a more specific insight generated by a general equilibrium tax model is contained by a further recent paper by Hamilton and Whalley (1986a); this time on border tax adjustments. In this paper they analyze the impact of changes between an origin and destination basis for sales taxes by major U.S. trading partners. Currently the U.S. has no broadly-based sales tax, whereas its major trading partners in Europe, Canada, and Japan, all do, having broadly-based sales taxes administered on a destination basis.

Hamilton and Whalley note the differences between policy and more academic literature on this issue. Over the years, there have been repeated calls from U.S. industry and other groups to offset the perceived effects of
these sales taxes abroad on U.S. trade. One preferred option is that the U.S. also introduce an indirect tax and administer it on a destination basis. The belief is that because of the destination basis abroad, exports leaving the U.S. have to cross a tax barrier whereas imports into the U.S. enter tax free. A similar tax in the U.S. would, in the current jargon, "level the playing field."

Academic literature has generally rebutted this argument, on the grounds that for broadly-based taxes any change between the origin and destination basis will be fully offset by a change in the exchange rate. In long run equilibrium there will be no real effects on trade flows from such a change, and the choice between the origin and destination base is a purely monetary issue, involving exchange rates only and with no real consequences.

However, as Hamilton and Whalley point out, the taxes at issue in U.S. trading partners are not broadly based, they are discriminatory. They also all have the feature that higher tax rates apply on manufactured products than on non-manufactures. Under such circumstances, if the country with which the U.S. is trading is a net exporter of manufactures, an origin-based tax operates akin to an export tax, while if the country in question is a net importer of manufactures, a tax on a destination basis operates largely as an import tax.

Hamilton and Whalley use a multi-country general equilibrium trade model that incorporates these sales tax effects. Their results show that if the U.S. were to persuade its three major trading partners to move to an origin-based tax rather than continue to use a destination basis, the U.S. would lose if the change involved Europe or Japan, but would gain if the change occurred
in Canada. They emphasize that from a U.S. national point of view, given the structure of these taxes abroad, it does not make sense to pursue a uniform approach with all countries on the border tax issue, contrary to current thinking in the U.S., nor does it necessarily make sense to press for foreign countries to use an origin basis. Instead, a pragmatic country-by-country approach should be taken, reflecting the bilateral balance of trade in taxed commodities. These results are, in fact, a reflection of the underlying data in which the U.S. is a net importer of manufactures in its trade with Europe and Japan, but a net exporter of manufactures in its trade with Canada.

All of these are examples of the ability of general equilibrium tax policy models to provide important perspectives on policy issues. To the extent that the results of these exercises challenge the broad-ranging perceptions which policy makers have in formulating their tax policy, they clearly make a major contribution to policy debate; a contribution which the results mentioned above hopefully demonstrate.

Some (such as the border tax example) are insights generated by trying to interpret model results from applying an existing model to an issue on which there were no previous results. Others (such as the broad implications for equity and efficiency objectives in tax policy) reflect the insights from quantification in a general equilibrium framework capturing price endogeneity.

They all, in my view, emphasize the potential usefulness of these models as broad-ranging policy evaluation tools, which can be applied along with other techniques to get a sense of what effects may be large or small, and what some of the implications of this or that tax alternative might be. Precise forecasting tools they are clearly not, but vehicles through which important insights can be generated they most definitely are.
VI. **ISSUES IN MODEL DESIGN AND USE**

Despite the claim that important insights have been generated by general equilibrium tax models, there are many difficulties with these models which both weaken the impact of results, and make some modellers cautious in promoting these models too vigorously. Lest readers get the impression that I am overpromoting their use, I will now highlight some of these problems.

**The Modelling of Taxes and Tax Rates**

A central and key difficulty with these models is selecting the appropriate treatment of the taxes to be studied. Any tax evaluated using a general equilibrium model has to be represented in some model-equivalent form, and a specification of tax rates is needed in order to complete the model. It is clear that the formulation adopted has important implications for the behaviour of these models, and to a degree, predetermines results.

A number of examples serve to illustrate the ambiguity that exists in theoretical literature as to what is the appropriate way to represent any particular tax and how this makes numerical modelling difficult. With the property tax, for instance, there has been a debate for some years on whether the tax is an excise tax or a tax on factor incomes. With the corporate tax there has been a series of different treatments in the literature since Harberger's (1962) original treatment of the corporate tax as a partial factor tax some years ago. Stiglitz (1973) suggested that the corporate tax should be considered as a lump sum tax. More recent literature has focussed on the tax as applying to equity financing by firms. Recent work by King and Fullerton (1984) and others has also emphasized how the effective tax rates that are faced by corporations vary, and have to be disaggregated to a very fine level to capture their marginal effects, even going to the level at which
project investment decisions are made. In their analysis, effective tax rates depend upon the financing vehicle used, eligibility for investment tax credits, loss carryforwards, and many other features. Fortin and Rousseau (1986) have also clearly demonstrated how modelling the implicit tax rates underlying transfer programmes can affect tax policy analysis.

Since all economic modelling involves choosing simplifications that capture the essence of the processes at issue, these problems should not be surprising, but the modelling of taxes and tax rates undoubtedly remains as a major difficulty. There is equally little doubt that current applied general equilibrium tax models do not always capture the levels of detail involved in ways which are wholly satisfactory, especially to those involved in policy decision making. The strength of general equilibrium models is their ability to capture interacting effects of different policy instruments among various markets within an overall framework representing the whole economy. Their weakness is their inability to deal simultaneously with large amounts of detail in many areas of the economy, and the detailed treatment of tax effects is often less than satisfactory.

Elasticities

Elasticities also represent a difficult area both for the applied general equilibrium tax models, and models used in other areas. In part this is because the empirical literature is not conclusive as to what are appropriate elasticity values to use. But the problem is more difficult than just selecting elasticity values, because the ways in which model parameters are generated from literature elasticities introduce many pitfalls.
In many areas there are very few elasticity estimates; and in those areas where elasticity estimates exist there are substantial differences of opinion of what appropriate elasticities are. It is something of a "cheap shot" to place too much blame on the applied econometricians, in part because it is undoubtedly a difficult area, but it does seem that over the last 10 or 15 years a major focus has been on hypothesis testing rather than parameter generation.

Two of the more important sets of elasticities used in general equilibrium tax policy models illustrate the difficulties: elasticities of labour supply, and elasticities of savings with respect to the real net-of-tax rate of return on capital. In both cases there is substantial ambiguity in the literature as to what the appropriate elasticity values are. There are further difficulties involved in using whatever literature estimates one is able to extract in model calibration.

An example is provided by the use of estimates of savings elasticities. In a model in which there are overlapping generations, for instance, there is no clear relationship between the aggregate elasticity of savings with respect to the real net-of-tax rate of return, and the intertemporal substitution elasticities in individual preferences. One can have an economy in which there is always zero savings because the economy is in a steady state, but there may be either large or small elasticities of substitution in individual preferences. To say that going from estimates of aggregate savings elasticities to estimates of intertemporal substitution elasticities in general equilibrium tax models is difficult is thus something of an understatement.
Aggregation

A further difficulty with the general equilibrium tax models is in choosing the appropriate level of commodity and industry aggregation in the model. On the one hand, one wants to keep the level of aggregation small both in order to generate clearer intuition as to the ways in which the models behave, and to keep execution costs within manageable bounds. A crude level of aggregation also has the virtue of making the data requirements for any given model more modest. On the other hand, claims to realism and the pressures from the policy process will often dictate much larger levels of aggregation. The most detailed of the applied general equilibrium tax models currently in use has around 30 to 40 commodities. But even this is hardly the level of detail with which tax policy makers typically operate in actually deciding upon appropriate tax treatment for individual industries and commodities. As regards household disaggregation, Slemrod's (1985) attempt to use micro unit data in general equilibrium tax models is the most ambitious attempt at disaggregation thus far, but as Slemrod notes this comes with a significant computational cost.

Calibration

Another area of concern with current models is the process through which models are calibrated. These methods involve calibrating a chosen model structure to a given benchmark equilibrium data set, in effect working from a constructed microconsistent equilibrium data set to the model parameters through a deterministic process which calculates parameters, not a statistical process of estimation.
This method of parameter generation has caused a fair degree of discomfort, especially to econometricians. This is because under calibration the numerical specification produced for any given model is not tested in any meaningful statistical sense since a purely deterministic calculation procedure is employed to generate parameter values. Econometricians who would like to see more than calibration to a single data observation have suggested system-wide estimation of models.

The difficulties with this are, however, well known. Overall system-wide estimation for a model with the large numbers of parameters used in the applied general equilibrium tax models would involve long time series. Also, if one partitions models and separately estimates model sub-systems, then when these parameters are reintroduced into the original model problems can arise. The equilibrium computed by the model and meant to be representative of the state of the world before any given policy change occurs may, in no way, correspond to what is known from national accounts and related data sources. Calibration continues to be widely used, in part because of its relatively easy implementation, and the difficulties of system-wide econometric estimation, but concerns persist.

**Functional Forms**

A further source of discomfort with the present stable of applied tax models is the widespread use of convenient functional forms such as Cobb-Douglas, CES, and LES. It is well known that recent econometric


6The Piggott-Whalley model of the UK, for instance, has around 20,000 parameters, if one includes all the share parameters in demand and production functions.
literature rejects the strong separability assumptions implicit in CES functions. Some have therefore suggested that more flexible functional forms should be used in these models, but, as yet, little work has been done using them. However, computational problems can result using translog functions because of the lack of global concavity properties for such functions.

Model Closure

All of the applied modellers who have dealt with tax policy issues have also confronted important issues of model closure. Closure refers to the need to close off models in some way in regard to features not central to the question being analyzed. The problem is that while the feature may not appear crucial for the issue under analysis, the closure treatment adopted may nonetheless have substantial impacts on the behaviour of the model.

One area where issues of model closure has arisen is with respect to foreign trade. Does one formulate a model in which the economy is a taker of prices on world markets or a maker of prices? And if the economy is a maker of prices, how is the behaviour of the foreign country with which one is trading to be specified? Another is the treatment of investment and savings, an area which has also been central in the applied general equilibrium development models. Yet another area is the treatment of government expenditures and public goods and transfers.

In all these areas, the experience that modellers have accumulated thus far suggests that model closure is both a delicate and difficult issue. As Whalley and Yeung (1984) have shown in the trade area it is unfortunately all too easy to adopt innocent-looking ad hoc closure rules, only to find with hindsight that these can seriously influence the behaviour of the model in
unintended ways. In the tax area, the same general message is almost certainly true.

**Issue-Specific versus General Purpose Modelling**

A further difficult issue of model design concerns the balance between issue-specific and general purpose modelling. In the early work done in the 1970s with general equilibrium tax models, the focus was very much on building general purpose models which yielded the capability to analyze several different taxes simultaneously.

While these models have been helpful in providing an overall assessment of how tax systems operate, their weaknesses have increasingly become apparent as specific policy analyses have been undertaken with them. Generally speaking, for the analysis of particular policy questions, model users often find that there are substantial amounts of superfluous detail in these models, while at the same time the amount of detail relevant to the policy question at hand is never wholly satisfactory. Model users have often found themselves having to modify parts of existing models relevant to the policy questions being examined, while carrying along significant amounts of excess baggage.

The reaction to this in the modelling work of the 1980s has been to focus on more issue-specific targeted modelling. However, issue specific models also have their weaknesses. One can easily find oneself repeatedly reconstructing models which are so closely related that it is an inefficient exercise. Also, in analyzing individual issues one misses many of the policy and other interactions which one captures in a general purpose model. While many of these effects are of secondary importance for the issue at hand, the difficulty is that, ex ante, it is never wholly apparent which of these effects are more important than others. One of the virtues of a large general
purpose model is, that by taking a first cut at a policy issue within an overall multi-purpose modelling framework, one obtains some indication as to which feedback elements are important for subsequent further development.

A partial resolution of this issue in future work may be to allow for policy questions to be analyzed through a range of models, so that general purpose broad-ranging models can give one set of perspectives, which can then be refined with more targetted issue-specific modelling.

These and other issues of model design in part reflect the evolution of the applied general equilibrium modelling area in general, and are not unique to tax models. Many of the difficulties listed here are inherent to the applied general equilibrium approach, and can probably never be adequately resolved to everyone's satisfaction. Repeated refocussing and refinement of modelling capabilities will, in the long run, probably yield more of value to the policy maker, and given the success of models thus far in generating policy insights, the expectation seems to be that with appropriate modifications these models can be taken further. But progress will probably be slow and incremental; dramatic advances on such fronts as elasticities, or calibration are unlikely to occur.

VII. CONCLUDING COMMENTS

In concluding, rather than summarize the paper it seems fitting to reflect briefly on what some of the desirable directions of future work in this area may be, based in part on the perspective given above on presently available models.
From my own experiences from working on modelling projects in both tax policy and other areas, one of the striking features of present models is the difficulty they demonstrate of working simultaneously on so many levels. An earlier paper (Shoven and Whalley (1984)) describing this as the need of modellers to be "jacks of all trades". People working in this area need to have a good grasp of economic theory, have to have a sense of the policy issues they are working on, need to be able to work on the computer, need to have an ability to interpret and communicate their results, and need to understand fully the data with which they are working. To me this all suggests the need for modelling teams. This has been the direction taken in other areas, particularly in natural sciences, and the need for an evolution in this direction in modelling work in economics seems clear. No doubt this is a direction work in the tax area will take as work more fully focussed on the policy questions of the day matures.

Another point of which I have been made acutely aware as a result of my own more direct involvement in the policy process is the difficulty of formulating policy-relevant modelling work in a way that is truly useful to policy makers. To be fully relevant, models have to be built close to the policy process, and with a fair amount of communication with those involved in policy making activity. Simultaneously, the pressures on those in policy making positions are such that they have limited time, energy (and sometimes interest) either to digest models or participate themselves in a dialogue with modellers. To develop modelling work that is closer to, and thus more useful to, policy making activity is undoubtedly a challenge for future work.

Finally, the focus of future work could stand further thought, rather than simply extend existing modelling work. Much of the applied general
equilibrium tax work in the last few years has been dominated by concerns over the intertemporal allocation of resources. Matters of income distribution, the treatment of particular goods and sectors by the tax system, and problems of tax compliance and administration have perhaps not received the attention that they might have merited. Also, the tax issues that face developing countries are so different from those with which the developed countries have to deal, that a refocussed effort on many of these questions would likely pay major dividends. A broadening of scope and coverage in the models that follow the present generation may therefore be in order.

I am not sure whether at the end of this the skeptics will be convinced that despite the caveats, numerical general equilibrium exercises are worthwhile. The curse of the model builder is that to be realistic the model inevitably becomes complex, but in the process increasingly takes on the guise of an impenetrable "black box" which is difficult to communicate. What is an acceptable simplification in theoretical work demonstrating a point is often not in numerical work with a claim to realism, but realistic modelling is by necessity not simple. Throw in the data problems, issues of model choice, and concerns over parameter specification, and the concerns of the skeptics become clear.

However, as I have tried to indicate in the paper, despite these concerns, many of which I view as inherently irreconcilable given our current state of knowledge, present models are contributing to policy debate in the tax area. And for the issues they address the alternatives are few. As a bridge between theory and policy concerns of the day they have a lot going for them, and as a way of generating null hypotheses where none exist or for
analyzing the validity of current perceptions they have a lot of appeal. Maybe their test will come as their attraction on grounds of technique alone begins to wane. Time will tell how they mature. However, it seems to me that their performance thus far gives reasonable grounds for at least continuing with their present use; and (dare I suggest it) for expanding their range of uses.
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# APPENDIX A

## Table A.1

<table>
<thead>
<tr>
<th>Model</th>
<th>Economy Studied</th>
<th>Base Year Data</th>
<th>General Purpose or Issue Specific Model</th>
<th>Dimensionality</th>
<th>Taxes Covered</th>
<th>Functional Forms</th>
<th>Main Policy Questions Analyzed</th>
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<tr>
<td>Piggott</td>
<td>Australia</td>
<td>1972–1973</td>
<td>General purpose</td>
<td>12 household groups, 18 domestic and 14 foreign industries</td>
<td>All major taxes and subsidies</td>
<td>Nested CES (demand) CES value-added (production)</td>
<td>Total and sectoral abolition of taxes and subsidies</td>
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<tr>
<td>Keller</td>
<td>The Netherlands</td>
<td>1973</td>
<td>General purpose</td>
<td>4 demand sectors 4 industries</td>
<td>Taxes on consumer goods and services, on capital goods, imports, labour capital and corporate income; lump-sum taxes</td>
<td>Nested CES (demand and production)</td>
<td>Changes in marginal marginal tax rates in various production and consumption sectors</td>
</tr>
<tr>
<td>Kehoe, Serra-Puche</td>
<td>Mexico</td>
<td>1977</td>
<td>General purpose</td>
<td>35 goods (including 14 production goods), 12 consumer groups</td>
<td>All major taxes including sector-specific taxes</td>
<td>Fixed coefficient-Cobb-Douglas (production) Cobb-Douglas (demand)</td>
<td>1980 Mexican fiscal reform</td>
</tr>
<tr>
<td>Kehoe et al.</td>
<td>Spain</td>
<td>1980</td>
<td>General purpose</td>
<td>12 production sectors, 27 goods, 8 households, 2 foreign sectors</td>
<td>Major taxes including turnover tax on production, social security taxes, taxes on foreign trade</td>
<td>Cobb-Douglas (demand and production)</td>
<td>Introduction of value-added tax</td>
</tr>
</tbody>
</table>
Table A.2

Policy Implications of Results from Models Listed in Table A.1

Piggott (Australia)

Replacement of all taxes and subsidies with an equal-yield export tax leads to a total welfare gain of 3.5% of NDP.

Keller (Holland)

Efficiency effects of most taxes are small (about 10% of the induced changes in public consumption); an increase in corporate income tax generates a positive excess burden that is twice the resulting change in consumption, with only a moderate burden borne by suppliers of capital.

Kehoe, Serra-Puche (Mexico)

Goal of stimulating activity in agriculture and foodstuffs by exempting these sectors from taxation appears plausible; all model scenarios estimate that the lowest and highest income households will benefit more from the tax changes considered than will the middle income groups.

Kehoe, et al. (Spain)

Introduction of value-added tax reduces consumer welfare by 2–3% on average, with the high income group experiencing greater reductions than the low income group; retention of the value-added tax accompanied by a reduction in social security contributions paid by employers leads to an overall improvement in welfare.
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Smith, Bruce. SOME COLONIAL EVIDENCE ON TWO THEORIES OF MONEY: MARYLAND AND THE CAROLINAS.


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8531C Freeman, Scott. INSIDE MONEY, MONETARY CONTRACTIONS, AND WELFARE.

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8617C Fried, Joel and Peter Howitt. FISCAL DEFICITS, INTERNATIONAL TRADE AND WELFARE.

8618C Trela, Irene, John Whalley, and Randy Wigle. INTERNATIONAL TRADE IN AGRICULTURE: DOMESTIC POLICIES, TRADE CONFLICTS, AND NEGOTIATING OPTIONS.
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<tr>
<th>Code</th>
<th>Author(s)</th>
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<td>Markusen, James R. and Anthony J. Venables</td>
<td>TRADE POLICY WITH INCREASING RETURNS AND IMPERFECT COMPETITION: CONTRADICTORY RESULTS FROM COMPETING ASSUMPTIONS.</td>
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<tr>
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<td>Hunter, Linda and James R. Markusen</td>
<td>PER-CAPITA INCOME AS A DETERMINANT OF TRADE.</td>
</tr>
<tr>
<td>8621C</td>
<td>Jones, Rich and John Whalley</td>
<td>A CANADIAN REGIONAL GENERAL EQUILIBRIUM MODEL AND SOME APPLICATIONS.</td>
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<td>Freeman, Scott, and Gregory W. Huffman</td>
<td>INSIDE MONEY, OUTPUT, AND CAUSALITY.</td>
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<td>Hamilton, Colleen, and John Whalley</td>
<td>DEALING WITH THE NORTH: DEVELOPING COUNTRIES AND GLOBAL TRADE NEGOTIATIONS.</td>
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