A COMPARISON OF METHODOLOGIES IN EMPIRICAL GENERAL EQUILIBRIUM MODELS OF TAXATION

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ABSTRACT

Computational general equilibrium models have proven useful in the area of long run analysis of alternative tax policies. A sizable number of studies have been completed which examine policies such as a value-added tax, corporate and personal income tax integration, a consumption or expenditure tax, housing subsidies, and inflation indexation. This paper reviews the methodologies used in these models. We focus on eight specific models and review in turn: levels of disaggregation, specification of the foreign sector, financial modeling, the measurement of effective tax rates, heterogeneity and imperfect mobility, factor supply, treatment of the government budget, and technical issues associated with implementation.

The paper includes some new experiments in connection with simulations of integration of the personal and corporate income tax systems in the United States. We compare the resulting welfare gains in models with different levels of disaggregation, and we discuss alternative justifications for specific disaggregations. We also examine the sensitivity of results to alternative specifications of households' endowments of labor and leisure.

Our survey underscores the importance of the assumed elasticities of labor supply with respect to the net of tax wage, and of saving with respect to the net of tax rate of return. Unfortunately, these are also parameters for which there is not a consensus in the economics profession. The survey finds that there are several aspects of modeling that are especially ripe for further progress: the roles of government and business financial decisions, the dynamics of a life-cycle approach, and the measurement of incentive tax and transfer rates.

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Introduction

Since Arnold Harberger (1962, 1966) introduced a general equilibrium model of taxation twenty years ago, his approach has been amended for the study of many economic issues. This paper is concerned with the methodology of one line of the descendants of the Harberger model: empirical models of government expenditures and taxes. We have chosen for comparison eight models that meet our criteria of "empirical" and "public finance." Although many small models, including Harberger's, have been outfitted with plausible parameters and used for policy analysis, we have focussed on models that have greater disaggregation, either in the number of producers or consumers, or both. These models are large enough so that they require computers for their solution. We have restricted our comparison to models whose primary purpose is evaluation of fiscal reform, rather than, for example, international trade, economic development or regional issues. Though tax policies undoubtedly are an integral part of some of these other models, they are associated with additional methodological issues that are outside the scope of this paper.[1]

This is primarily a paper about methodologies. We look at how these empirical public finance models have generalized the Harberger method. We also look at differences among them in their specifications. Sometimes these variations are due to differences in applications of these models. When the models are used for evaluating similar reforms, however, we examine results to determine the implications of alternative specifications. More briefly, we discuss some extensions that appear imminent, as well as theoretical innovations that have not yet been incorporated into empirical general equilibrium models.

We view this comparison of empirical general equilibrium models of taxation as an exercise that might eventually be conducted jointly by the proprietors of these various models. The authors of the current paper are associated with the Fullerton, Shoven, Whalley model and its extensions. As such, we are more knowledgeable about sensitivity experiments using our models, and also have been able to perform some new experiments specifically for this paper. We have inferred sensitivity results for other models analytically by examining published results. We recognize that this is only a second-best approach. The design and execution of common simulations have been tried successfully by builders of macroeconometric models (see Fromm and Klein 1976), but only in a preliminary way for models of tax incidence (see Devarajan, Fullerton, and Musgrave 1980). We hope that we have identified areas here where joint ventures might provide further understanding of general equilibrium models.

The discussion starts with brief overviews of the Harberger model and our selected models.

I. Harberger Model

The Harberger model has been expounded in many articles in addition to his own. These include Mieszkowski (1969), McLure (1975), and Atkinson and Stiglitz (1980, lecture 6). Here, we set out the assumptions verbally; the other sources may be used for an algebraic description. Harberger's model was designed to examine the interindustry distortion from the corporate income tax. He assigned industries to the corporate and noncorporate sectors based on whether they were "heavily" or "lightly" taxed, according to data of Rosenberg (1969) for the U.S., 1953-59.[2] Harberger's noncorporate sector included agriculture, housing, and crude oil and gas, while his corporate sector included all others. Each sector produced a single output in perfect competition using homogeneous, perfectly mobile labor and capital, the supplies of which were fixed in the aggregate. Harberger's results on the burden of the corporate income tax depended in part on the substitutability of labor and capital in production. This "factor substitution effect" (Mieszkowski 1969) was due to the fact that the corporate income tax was viewed as a differential tax on capital income only. Harberger simulated his model under a variety of assumptions on the elasticity of substitution in each sector.

On the demand side, the model was simpler. There was only one consumer, so that Harberger was limited to analyzing the functional, but not the personal, distribution of income. The government was assumed to display the same preferences as the consumer in spending its tax revenues. This specification is formally equivalent to a model in which consumer preferences are homothetic, and in which tax revenue is returned as a lump-sum subsidy. Thus, using Mieszkowski's terminology, there was no "demand effect" because the model did not have different consumers purchasing different bundles of goods. There was an "output effect," however, because the extra tax was on output of only the corporate sector. Each sector's output could have a different price elasticity of demand, and each output could have different factor intensities.[3] Harberger had data on factor intensities and used a range of assumptions about demand elasticities.

The solution technique involved total differentiation, so that, technically speaking, the model was appropriate only for small changes in the tax code. As originally formulated, the model assumed no pre-existing tax distortions but this was amended by Ballentine and Eris (1975). Shoven (1976) corrected Harberger's model for conceptual errors in the measurement of the surtax, as well as arithmetic errors. The often-quoted outcome of all these studies was that capitalists bear the full burden of the corporate income tax. Harberger's estimate of the efficiency cost, corrected by Shoven, was between six and fifteen percent of the revenue generated, or 0.3 to 0.6 percent of GNP.

II. Empirical General Equilibrium Models of Taxation

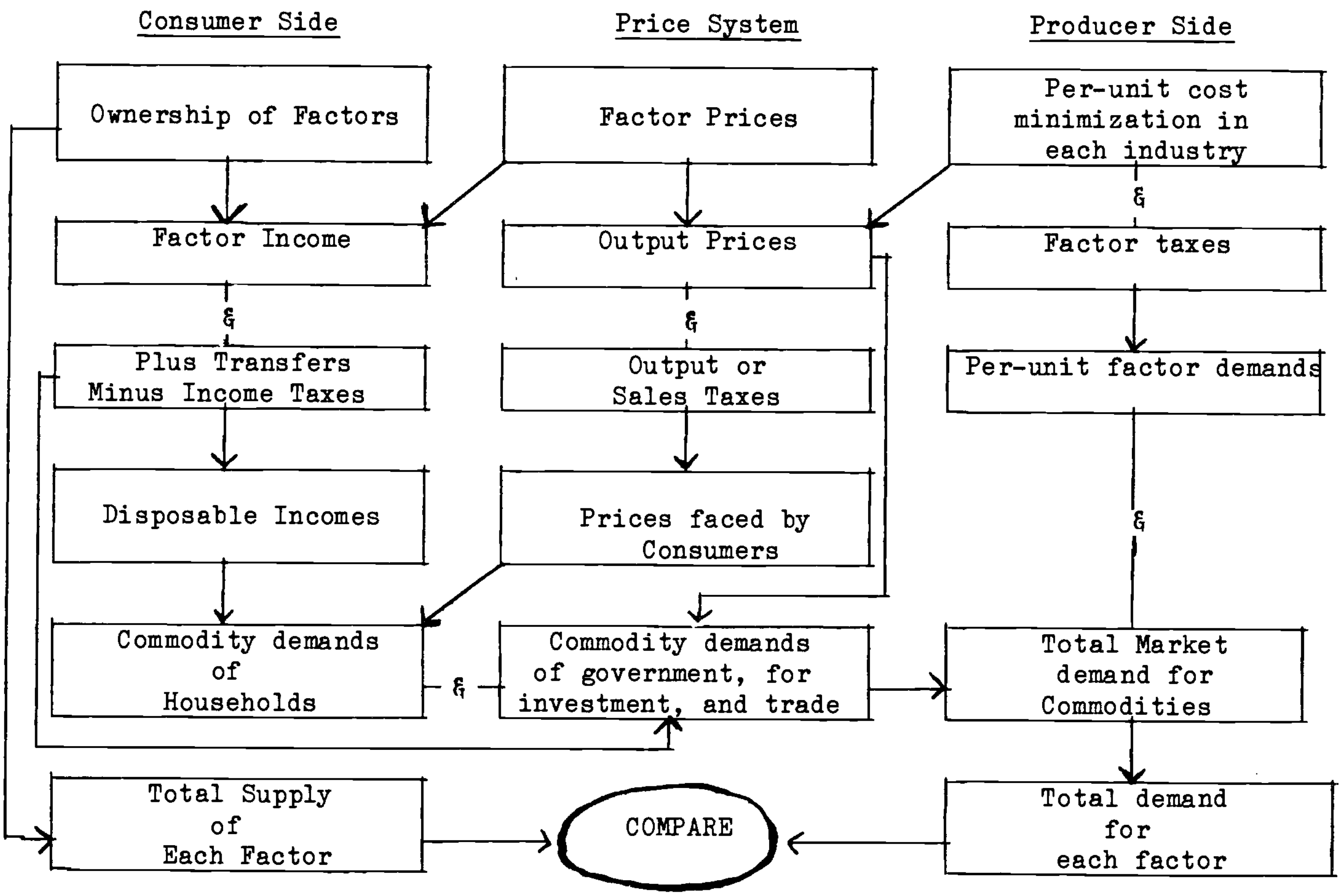
The general techniques of Harberger were quickly applied in models that relaxed some of the restrictive assumptions. The empirical models in our study are further elaborations of these earlier extensions. Shoven and Whalley (1972, 1973) and Shoven (1976) used the Scarf simplicial search algorithm to solve disaggregated versions of the Harberger model. With this new computational technique, they could properly examine large changes in the corporate tax rate. Feldstein (1974a, 1974b, 1978) studied capital income tax incidence by comparing steady states in a one-sector model with variable factor supply, and Ballentine (1978) developed the dynamic (steady-state) counterpart to Harberger's two-sector model. Boadway (1979) examined transitions between steady states. In the area of financial analysis, Feldstein and Slemrod (1980) examined the effects of the corporate income tax on portfolio allocation, and Feldstein, Green, and Sheshinski (1978) and Ballentine and McLure (1980) examined its effects on dividend payouts.

As might be expected, the results of these studies indicated a substantial range of answers on incidence of the corporate income tax. Particular findings will be mentioned below as we review specific features of applied general equilibrium models.

What is the profile of a "typical" applied general equilibrium model of taxation? Figure 1 provides an example. The prototypical model has several industrial sectors, in which fully mobile and homogeneous labor and capital are used in production in a profit-maximizing combination. There are several household groups, defined by income, who are endowed with labor and capital in varying amounts. These groups also derive income from government transfers. Households allocate their income across consumption goods according to principles of budget-constrained utility maximization. There are usually *ad valorem*

Figure 1

Diagram of a Typical General Equilibrium Tax Model



Competitive equilibrium achieved when:

1. Demands equal supplies for all goods and factors;
2. Zero profits (net of taxes) prevail in all industries; and
3. Agents are on their budgets (e.g., total government expenditures equal to receipts from taxes and from selling endowments of capital or "bonds").

taxes on incomes, factors, and outputs, and these enter into the appropriate production and consumption decisions. Equilibrium is reached when demand and supply are equal for all goods and factors. Generally, other features of the equilibrium are that producers receive no excess profits and that all agents are on their budget constraints. Solution for the equilibrium is accomplished by using a computer algorithm. Features such as endogenous factor supplies and financial assets are not part of the prototype model. As will be shown, none of the models in our survey adheres strictly to this blueprint.

The models included in our comparison are:

(1) Piggott-Whalley (PW) (1976, 1982)

(2) Fullerton-Shoven-Whalley (FSW) (1978, 1981, 1982)

(3) Ballentine-Thirsk (BT) (1979)

(4) Keller (1980)

(5) Serra-Puche (1979, 1982)

(6) Slemrod (1980, 1982)

(7) Fullerton-Gordon (FG) (1982)

(8) Auerbach-Kotlikoff (AK) (1982)

The key features of these models are summarized in Table 1, which provides a structure for the discussion. The first five models in the list, those of Piggott and Whalley, Fullerton, Shoven, and Whalley, Ballentine and Thirsk, Keller, and Serra-Puche, are large, general-purpose models for different countries, the United Kingdom, the United States, Canada, the Netherlands, and Mexico, respectively. They each have considerable disaggregation of production and demand. They are designed to study a variety of taxes, transfers, and subsidies in addition to the corporate income tax. Despite these similarities, the authors have made different decisions on modeling factor mobility, aggregate

Table 1

Features of Applied General Equilibrium Taxation Models

	Piggott Whalley (1)	Fullerton Shoven Whalley (2)	Ballentine Thirsk (3)	Keller (4)	Serra-Puche (5)	Slemrod (6)	Fullerton Gordon (7)	Auerbach Kotlikoff (8)
Country	U.K.	U.S.	Canada	Netherlands	Mexico	U.S.	U.S.	U.S.
Number of Producers	33 CES	19 CES	7 CES	4 CES	14 Cobb-Douglas	4 Cobb-Douglas	19 CES	1 Cobb-Douglas
Number of Consumers	100 groups by occupation and income	12 income groups	12 income groups	2 income groups	10 income groups (urban & rural)	9 income groups	12 income groups	55 age cohorts
Solution Technique	Newton Method	Merrill's Algorithm	Linear approximation	Linear approximation	Merrill's Algorithm	Gauss-Seidel iteration	Merrill's Algorithm	Gauss-Seidel iteration
Year(s) of Data	1973	1973	1969	1973	1977	1962/1977	1973	Plausible/ Hypothetical
Parameter Deviation	Backward solution, exogenous parameters, and some separate estimation	Backward solution with selected exogenous parameters	Backward solution and sensitivity analysis	By assumption and backward solution	Backward solution	Plausible exogenous parameters with some backward solution	Backward solution, exogenous parameters, and some separate estimation	By assumption and sensitivity analysis
Factors of Production	K,L, each mobile and homogeneous	K,L, each mobile and homogeneous	K,L, each mobile and homogeneous; land used in two sectors	K, skilled labor, unskilled labor, imports	K, rural labor, urban labor, and capital	K,L, each mobile and homogeneous, but risk varies by	K,L, each mobile and homogeneous, but risk varies by use	K,L, each homogeneous (one sector)

Features of Applied General Equilibrium Taxation Models (Cont'd)

	Piggott Whalley (1)	Fullerton Shoven Whalley (2)	Ballentine Thirsk (3)	Keller (4)	Serra-Puche (5)	Slemrod (6)	Fullerton Gordon (7)	Auerbach Kotlikoff (8)
Input/Output matrix?	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Labor/Leisure choice?	Yes	Yes	No	Yes	No	No	Yes	No
Time path?	Static equilibria only	Sequence of static equilibria	Static equilibria only	Static equilibria only	Static equilibria only	Static equilibria only	Sequence of static equilibria	Simultaneous solution for 200 years
Endogenous capital stock?	Saving endogenous, K fixed in static calculation	Not in one period, but saving augments K through time	Fixed domestic capital, variable use of foreign capital	Saving endogenous, K fixed in static calculation	Saving endogenous K fixed in static calculation	Fixed total capital	Not in one period, but saving augments K through time	Growing endogenously over time
Foresight/ Expectations	Myopic	Myopic	(no saving)	Fixed marginal propensity to save	Myopic	(no saving)	Myopic	Perfect
Differing Portfolios?	In the data, yes; in the model, no	In the data, yes; in the model, no	No	In the data, yes; in the model, no	No	Different returns on six financial and real assets based on portfolio demands	Same as FSW, but tax rates on different assets reflect different portfolios	No

Features of Applied General Equilibrium Taxation Models (Cont'd)

	Piggott Whalley (1)	Fullerton Shoven Whalley (2)	Ballentine Thirsk (3)	Keller (4)	Serra-Puche (5)	Slemrod (6)	Fullerton Gordon (7)	Auerbach Kotlikoff (8)
Risk	No separate risk premia, all returns certain	No separate risk premia, all returns certain	No separate risk premia, all returns certain	No separate risk premia, all returns certain	No separate risk premia, all returns certain	Explicit variance in rates of return	Separate risk premia, dependent on asset and industry	No separate risk premia, all returns certain
Government Budget	Balanced, can calculate Lindahl solution	Balanced each period	Balanced	Balanced	Deficits allowed with government bonds	Balanced	Balanced each period	PV of expenditures = PV of revenue - initial debt (not balanced each period)
Equal Tax Yield	Allowed through broad based sales tax	Allowed through lump-sum taxes or increased personal rates	Allowed through adjusting any rate	No. Allows changed government spending	No	Allowed through increased personal rates	Allowed through lump-sum taxes or increased personal rates	Allowed through adjusting any rate
Taxes Included	All major U.K. taxes and subsidies	All U.S. taxes	All major Canadian taxes and subsidies	Linear income tax, factor taxes, sales taxes	Income taxes, sales tax, VAT, tariffs	Corporate and personal income tax, property tax	All U.S. taxes	Capital tax, labor tax, consumption tax
Bankruptcy Costs	No	No	No	No	No	No	Yes	No
Foreign Sector?	Balanced trade with Armington assumption	Balanced trade with constant elasticity	Imports and exports are distinct goods; balanced trade with flow of K	Foreign household sells distinct good (fixed world prices); balanced trade with flow of K	Unbalanced trade, but exogeneous	None	Balanced trade, constant real value of trade in each good	None

Features of Applied General Equilibrium Taxation Models (Cont'd)

	Piggott Whalley (1)	Fullerton Shoven Whalley (2)	Ballentine Thirsk (3)	Keller (4)	Serra-Puche (5)	Slemrod (6)	Fullerton Gordon (7)	Auerbach Kotlikoff (8)
Imperfect Competition	No	No	No	No	No	No	No	No
Monetary Policy?	No	No	No	No	No	Liquid assset is a use of K	No	No
Involuntary Unemployment?	No	No	No	No	No	No	No	No
So far use to Evaluate:	Housing subsidies, VAT, overall effects of each tax	Integration, consumption tax, VAT, capital or labor tax changes	Housing subsidies, intergovern-mental grants	Changes in VAT, import levies, factor taxes, overall effects	VAT	Integration, effects of inflation	Integration	Consumption tax, capital vs. labor taxation
Distributional Effects	Calculates CV, EV, Gini coefficients, Atkinson measure social welfare	Changes to current income with Paasche or Laspeyres indices CV or EV from static utility	Change to current income	Compensating and Equivalent variations	Changes in utility measures	Changes to utility measures, based on current income and risk bearing	Same as FSW but not reported	Among age cohorts using utility measure
Efficiency Effects:								
Intersectoral	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Intertemporal	No	Yes	No	No	No	No	Yes	Yes

Features of Applied General Equilibrium Taxation Models (Cont'd)

	Piggott Whalley (1)	Fullerton Shoven Whalley (2)	Ballentine Thirsk (3)	Keller (4)	Serra-Puche (5)	Slemrod (6)	Fullerton Gordon (7)	Auerbach Kotlikoff (8)
Debt/Equity	No	No	No	No	No	Adjustments, but no efficiency loss of distortion	Yes	No
Dividend Payout	No	No	No	No	No	Adjustments, but no efficiency loss of distortion	"Measured" at zero	No

factor supplies, budget balance, and the foreign sector.[4] They also employ different solution techniques.

The next two models, of Slemrod and of Fullerton and Gordon (an extension of the FSW model), are more fully specified than the previous models in the area of financial behavior. Yet they have interesting differences between them in how financial decisions are made by households and firms, in saving behavior, in disaggregation, and in parameter derivation. The FG model also differs from all the other models in that marginal tax rates on capital differ from average tax rates.[5]

The Auerbach-Kotlikoff model was designed for study of intergenerational incidence. It is also unique in its use of perfect foresight rather than myopic expectations.

III. Model Comparisons

The remainder of the paper is organized by methodological areas in which the applied models have contributed to the tax incidence literature. We review in turn: disaggregation, specification of the foreign sector, financial modeling, the measurement of effective tax rates, heterogeneity and imperfect mobility, factor supply, treatment of the government budget, and technical issues associated with implementation.

1. Disaggregation

a. Production Sectors

The applied general equilibrium taxation models use disaggregated data on both production and consumption. We can delineate two levels of disaggregation of the production data: medium, including Slemrod (4 sectors), Keller (4), BT (7 domestic plus 1 foreign), and high, including FSW (19), Serra-Puche (14), PW (33 domestic plus 27 foreign). The AK model, designed to evaluate taxes on consumption and labor income, has no disaggregation of production.

Slemrod and BT preserved Harberger's specification of a homogeneous corporate sector, though each has refined the definition somewhat. For example, Slemrod correctly observed that the crude oil and gas industry is largely corporate despite its low rate of capital taxation. Each also disaggregated the noncorporate sector further. Slemrod's breakdown was composed of agriculture[6] and two types of housing, owner-occupied and rental. Because imputed rents and capital gains in the owner-occupied housing sector are virtually untaxed, there is a subsidy which causes misallocation of resources within housing and which is aggravated by inflation. BT separated out agriculture, as well as a homogeneous housing sector. Because of their interest in government expenditure programs, they distinguished urban transit services and local public services from other services. There are separate import and export sectors, as discussed in Section III.2 below.

The FSW and PW models have disaggregation by industry, with each industry representing a fixed mix of corporate and noncorporate enterprises. With this specification, the effects of the corporate income tax are modeled directly. FSW, for example, have simulated elimination of taxation at the corporate level by deleting this component of capital income taxation in each industry, and assigning corporate profits to taxation at the household level. This is in contrast to the Harberger approach, which equalized taxes in the corporate and noncorporate sectors. Tax rates differ from industry to industry not only because of the extent of incorporation, but also because of the differential tax reductions from investment tax credits and depreciation allowances.

The U.K. tax system, by contrast, has provided substantial relief from double taxation of dividends since 1973, when a partial integration measure was introduced. The advantage of disaggregation by industry in the PW model lies instead in the ability to evaluate specific capital subsidies, such as regional development grants and borrowing subsidies to nationalized industries.

These two models (FSW, PW) may be compared with the previous two (Slemrod, BT) with respect to housing and the foreign sector. The FSW model does not disaggregate the housing sector. The PW model, on the other hand, has private housing services and public (local authority) housing services. The latter category consists of subsidized rental housing and accounts for the majority of the rental housing stock in the U.K. This *ad valorem* rent subsidy causes misallocation of resources.

Most industries in the PW model are composed of competing domestic and foreign producers, each subject to different tax rules. This treatment is described in section III.2 below.

b. The benefits from disaggregation of production

The foregoing description has shown that the applied general equilibrium models have disaggregated the Harberger sectors in many ways. In this section, we examine which degree of disaggregation is necessary on the grounds that Harberger argued were important, namely differences in tax rates, capital intensity, consumer price elasticities of demand for outputs, and degrees of factor substitution. We then take advantage of a feature of the FSW model that allows the level of aggregation to be changed. We use this feature to measure the importance of disaggregation in simulations of integration of corporate and personal income taxes.

The evidence on disaggregation appears to be that the "first level" disaggregation -- to a corporate sector, housing, and agriculture -- is worthwhile because of differences in factor intensities. Further disaggregation of production is justified on other grounds, expecially the existence of different tax rates by industry.

The disaggregated models show that production of housing services is by far the most capital intensive industry. Other industries that rank fairly high in capital intensity are agriculture (in FSW and PW), utilities (in PW), and paper and printing and mining (in FSW).

In general, the evidence on demand elasticities for outputs and factors is not robust enough to point to significant interindustry differences. The FSW and Slemrod models assume Cobb-Douglas demands, so that, within an income class, relative expenditures on consumption goods are constant. Even though BT assume differential price elasticities, they conclude that the combined effects from capital-labor ratios and consumer demands generally produce a weak output effect. The one exception occurs when the relative price of land changes, since land is assumed to be used in only some sectors. The PW model has two layers of substitution elasticities among domestic goods. The elasticity of substitution between similar consumption items, such as coal and gas, is generally higher than the substitution between their aggregate and other "blocks" of goods. The elasticity of substitution between each pair of "blocks" is the same, 0.5. Keller has similar blocking of commodities. In light of the BT findings, however, these differences in consumer demand elasticities may not be very important.

On the substitutability of capital for labor in production, Slemrod assumes Cobb-Douglas functions. The FSW, BT, and PW models use CES production functions, but the elasticities are close to 1 for most industries.[7] The most dramatic departure from this pattern is in housing, where Slemrod assumed that only capital is used in production, and where BT and PW posited a very low elasticity of substitution between capital and labor. There is another production-based argument for separating out housing and agriculture in the BT model, because land is a separate factor of production and is used only in these industries.

We turn next to our experiments with disaggregation of production. In the first part of Table 2, we review the results of Shoven (1976), who corrected two errors of Harberger (1966). He then applied the algorithmic approach to Harberger's two-sector model and an alternative 12-sector model. When Harberger's simple arithmetic error was corrected, the efficiency gain from capital tax rate equalization was reduced. When his conceptual error on the definition of capital units was corrected, however, the efficiency gain estimate was increased approximately back to the original estimate. These corrected Harberger estimates are shown in row 1 of Table 2.

Row 2 shows that when the same data are used in the algorithmic approach, rather than the linear approximation, welfare gain estimates are changed only slightly. Row 3 shows that disaggregating the data to 12 producers has the effect of raising the estimate. This result can be explained intuitively as follows. The two-sector model captures only the misallocation of capital between the two sectors, not within each sector. If the corporate sector is disaggregated into some high-tax industries and other relatively low-tax industries, as is possible with a 12-sector model, then further misallocations can be captured. Welfare gains from eliminating these misallocations will be greater. A proof that welfare gains must increase with disaggregation for a policy which equalizes capital tax rates is given in Shoven (1973).

Table 2

Disaggregation Experiments*

Elimination of Surtax in the Corporate Sector	Efficiency Gain	
	$ billions (1957)	% of NNP
(1) Corrected Harberger model, 2 sectors	.625-1.79	0.3-0.6
(2) Shoven-Whalley model using Scarf algorithm; 2 sectors and 2 consumers	.69-1.49	0.3-0.5
(3) Shoven-Whalley model using Scarf algorithm; 12 sectors and 2 consumers	.92-2.11	0.4-0.7

Integration of the Corporate and Personal Income Tax	"Dynamic" Efficiency Gain		"Static" Efficiency Gain	
	$ billions (1973)	% of P.V. income	$ billions (1973)	% of expanded income
(4) FSW model, 2 sectors (A)	87.8	.176	-1.77	-.10
(5) FSW model, 2 sectors (B)	219.8	.441	.79	.05
(6) FSW model, 5 sectors	251.0	.503	.27	.02
(7) FSW model, 19 sectors	344.4	.691	2.34	.14

*See text for further description. Lines (1)-(3) are taken from Shoven (1976).

In the second part of Table 2, we display results from new simulations with the FSW model. These results are not really comparable to the earlier Shoven (1976) results, because the model is quite different. The "dynamic" efficiency gains refer to the present value of the sum of 12 consumers' compensating variations. This concept captures both intertemporal and intersectoral distortions, each of which is reduced through the integration of personal and corporate taxes. The "static" efficiency gains refer to the mean of Paasche and Laspeyres measures for the change in expanded national income (including leisure valued at the net-of-tax wage).

The two parts of Table 2 are also not comparable because full integration does not imply complete capital tax equalization. Some other tax distortions remain, including the low taxation of real estate caused by the nontaxable nature of imputed owner-occupant net rents. Integration is, however, comparable to the policy proposals simulated in some of the other models reviewed here. Integration, as we have defined it, includes the elimination of the corporate income tax, the full taxation of corporate income at the personal level, and the indexing of capital gains for inflation.[8] Table 3 shows the wide variation of the 19 capital tax rates of the FSW model before any policy change, as well as the lower and less varying capital tax rates implied by full integration.

Row 7 of Table 2 shows the results of integration for the full-sized (19 sector) FSW model. Static welfare gains as a percent of income are much lower than for Shoven (1976) for at least two reasons. First, capital tax rates are not completely equalized as just discussed. Second, and more important, this model uses an equal yield feature which increases personal tax rates multiplicatively until government can attain the same utility level as in the benchmark. Because all 12 personal tax rates are multiplied by the factor 1.16

Table 3

Capital Tax Rates (on Net Income) Before and After Integration, for Each Aggregation

	Capital Tax Rates	
	Before	After
19 Industries		
(1) Agriculture	.54	.46
(2) Mining	.95	.71
(3) Crude Petroleum and Gas	1.02	.70
(4) Construction	2.10	.68
(5) Food and Tobacco	3.47	.88
(6) Textile, Apparel and Leather	2.53	.75
(7) Paper and Printing	1.63	.63
(8) Petroleum Refining	.46	.44
(9) Chemicals and Rubber	1.87	.60
(10) Lumber, Furniture, Stone	.91	.52
(11) Metals and Machinery	1.72	.66
(12) Transportation Equipment	23.50	4.88
(13) Motor Vehicles	1.29	.47
(14) Transportation, Comm., Util.	1.70	.89
(15) Trade	1.85	.83
(16) Finance and Insurance	1.99	1.35
(17) Real Estate	.63	.56
(18) Services	.86	.57
(19) Government Enterprises	.26	.26
(Weighted Average)	.97	.61
5 Industries		
Agriculture	.54	.46
Real Estate	.63	.56
Services	.86	.57
Government Enterprises	.26	.26
All Others	1.57	.76
(Weighted Average)	.97	.61
2 Industries, Version A		
Agric., Crude Pet., Real Estate (1,3,17)	.61	.54
All Others	1.37	.69
(Weighted Average)	.97	.61
2 Industries, Version B		
Agric., Crude, Refined Pet., Real Estate, Gov. Ent. (1,3,8,17,19)	.58	.51
All Others	1.62	.77
(Weighted Average)	.97	.61

in the new equilibrium, labor/leisure choices are further distorted. Welfare losses on that margin offset the gains from capital allocation improvements. The dynamic measure includes the same offsetting effect but also includes the gains on the intertemporal margin from capital tax reductions.

We are now prepared to address the following question: how much of the difference between the FSW results and other results are due to disaggregation in production? Our experiments make use of a variable aggregation procedure designed and built for the FSW model by Lawrence Goulder. We first aggregate to the two sectors defined by Harberger (and used by Shoven). In this two-sector model, called Version A in the tables, the first sector includes agriculture, crude petroleum, and real estate, while the other sector includes all other private industry. Harberger divided the economy this way because the first sector was supposed to represent low-taxed industries.[9]

Our Table 3 shows that approximately the same ordering exists in the 1973 data set for the FSW model, except that the tax rate for petroleum refining is even lower than that of agriculture. This data set also includes "government enterprises" as an industry that was not considered in the 1957 data of Rosenberg (1969). This sector also has a very low tax rate on capital.

It thus makes sense to add petroleum refining and government enterprises to the low-tax sector, and we refer to this two-sector model as Version B. The bottom of Table 3 shows that the selection of industries for a two-sector model is very important. Benchmark capital tax rates for Version A, corresponding to the Harberger aggregation, are considerably closer together than are the tax rates for Version B. Equalization or integration cannot be expected to provide as great a gain in efficiency, especially since these distortions vary with the square of the surtax.

The efficiency gain results in rows 4 and 5 of Table 2 bear this out. Welfare gains from the "Harberger aggregation" are considerably smaller than from Version B where the industries are more appropriately grouped.[10]

Next we aggregate the FSW model into groups of industries that are similar to the models of Slemrod (1982) and Keller (1980). Those models use four industries corresponding to agriculture, real estate, services, and other "corporate" industries.[11] We also break out government enterprises as a fifth industry, since this activity is not similar to other corporate activities. When this model is used to simulate integration, the welfare effects are shown in row 6 of Table 2.

Compare the dynamic measure for the "correct" two-sector model of Version B, the 5-sector model, and the 19-sector model. This measure increases from $220 billion (in 1973 dollars) to $251 billion, and to $344 billion, respectively. It would seem from this evidence that the 5-sector model does not do much to improve upon the two-sector model. Indeed, when we look at the capital tax rates of Table 3, we see that the rates for the three private "noncorporate" industries are quite similar (.54, .63, .86) in the benchmark equilibrium. If the point of disaggregation is to capture differing effective tax rates, this is not the place to do it. The top of Table 3 reveals that there is more variance of tax rates among the industries of the corporate sector. This contrast explains the further change in welfare estimates from disaggregating to 19 industries. It is difficult to say whether further disaggregation would be warranted.

c. Disaggregation of Households

Most of the applied general equilibrium models have disaggregated households by income class. A couple have also distinguished households by age, occupation, and family composition. In this section we survey what differences there are in the sources and uses of income by these classes, and what additional insights may be gleaned by this disaggregation. The information on disaggregation is relevant not only for the basic tax structure that is under review, but also for the financing of the tax change, which may now have distributional effects as well.

The BT, FSW, Serra-Puche, and Slemrod models divide households into about a dozen groups by incomes. Serra-Puche distinguishes between urban and rural groups. Piggott and Whalley have 100 groupings by income, family composition, occupation, and work status. The latter two categories specify whether a household head is not employed, retired, or working in one of the following three occupations: manual employee, non-manual employee, or self-employed. The Auerbach-Kotlikoff model has 55 age cohorts. During its working years, each cohort's wage grows at the fixed rate of increase of labor productivity; upon retirement, income consists of earnings from previous saving.

Where there is a progressive income tax, the range of marginal income tax rates may be taken as one indication of the degree and pattern of disaggregation of households by income. Comparing the FSW and Slemrod models of the U.S., we see that the first disaggregates more finely at the low end of the scale, while the latter disaggregates more at the high end. The ranges of marginal tax rates in these models are 1 to 41 percent and 14 to 82 percent, respectively. This pattern corresponds to the emphasis of the Slemrod model on portfolio behavior; the distribution of wealth is more concentrated at the top than is income. Consumption data for very high income groups, by contrast, are not available, and were imputed in Slemrod's study. Slemrod's data on tax rates also reflect the tax law prior to the Revenue Act of 1964.

The use of marginal tax rates is less satisfactory for comparing the levels of disaggregation in models of different countries, since personal tax systems differ significantly. We can, however, compare incomes for the lowest and highest groups relative to the group with median income, and look at the numbers of groups below and above the median income level. By these measures, the BT model's pattern of aggregation is roughly similar to that of the FSW model.[12]

We turn now to evidence on the differences among household groups in the sources and uses of income. On the factoral distribution of income, all the models with disaggregation only by income show a similar U-shaped pattern for the capital-labor ratio of income: the lowest and highest income groups receive the highest shares of their income from capital. Slemrod's data indicate that the very rich, those with income over $50,000 in 1962, derived almost all of their earnings from capital. For the low income group, the data reflect the earnings pattern of retired persons. On this last point, the PW data are more specific. At least for the UK (and the range of incomes PW consider), the capital share of income is very high for retired persons[13] and self-employed persons. The differences among income groups within an occupation are in fact much less obvious. The AK model, with its stylized income pattern across households, has the capital income share rising monotonically with age.

There are two aspects to the uses side of household behavior: allocation to consumption categories and allocation to saving categories. For consumption, the models indicate that the expenditures on food and housing each decline markedly with income. Expenditures on services, on the other hand, tend to rise somewhat with income. These patterns leave a progressive profile of consumption of manufactured products, which are produced by heavily corporate industries. The evidence on consumption, then, supports disaggregation of the production sectors into agriculture, housing, and other.

While consumption data support some disaggregation of income groups, a stronger argument for disaggregation may be made in models that have portfolio behavior. Slemrod's data show tremendous variation in asset holdings by income groups. In version "B" of his model, Slemrod distinguished six assets: corporate equity, taxable and tax-exempt debt, rental and owner-occupied housing, and liquid assets. The portfolio of the lowest group is about 70 percent in owner-occupied housing and liquid assets, while for the top group it is almost entirely in corporate equity and tax-exempt debt. Owner-occupied housing is the most important single asset for households with incomes under $25,000 (in 1962 dollars).

2. Foreign Sector

The general equilibrium approach has long been used in models of international trade. Boadway and Treddenick (1978) extended this literature in modeling the effects of tariff policies on the allocation of resources across domestic industries. International trade is now part of the FSW model of the United States, as described in Goulder, Shoven, and Whalley (1982),[14] and of all the models that we review of other developed countries. All these models feature some form of balanced international trade, which sometimes refers just to net exports of goods and services, and sometimes encompasses capital flows as well. No models include flows of international reserves or a role for monetary policy.

Even within the area of commodity flows, there has been unexpected variation in modeling exports and imports. This may be due to data limitations in different countries. In the BT model, imports are aggregated to form one good and are considered to be imperfect substitutes for all other consumption goods. In Keller's model, imports are quasi-intermediate: producing output involves substituting among domestically-produced goods and foreign-produced goods as inputs. In PW, there is an explicit distinction between imports used for intermediate inputs and for final consumption. Consumers have CES demand functions between pairs of competing domestic and foreign goods while intermediate imports are used in fixed proportions in production.

The treatment of exports is somewhat more uniform. In most cases, trade elasticities govern what fraction of a sector's output will be exported. In the Ballentine and Thirsk model, however, export production takes place in two export sectors, one of which is a price-taker in supply and the other of which has some market power in international trade.

These differing specifications make parameterization of elasticities of substitution difficult. Often the simplifications used in modeling do not correspond to the specifications in other empirical studies which are used to provide parameters (see Section III.8a for a discussion of parameterization). In this situation, performing tests of alternative assumptions is important.

The model of the foreign sector is critical in evaluating changes from an origin-based tax to a destination-based tax, or vice versa. The corporate income tax is an example of the former: it is collected in the production of goods used for export but not for import. On the other hand, the value-added tax is generally rebated on exports and applied to imports. Shifts from one to the other could cause large changes in import and export prices, and, depending upon trade elasticities, large changes in net exports. PW (for the U.K.) and Goulder, Shoven, and Whalley (for the U.S.) found that movements in terms of trade caused significant welfare changes.

Endogenizing capital flows may significantly change the evaluation of changing capital taxes, as Goulder, Shoven, and Whalley found for the U.S. They estimated that the domestic welfare gain from corporate tax integration would be significantly increased if there were a fluid world capital market. The reduced tax would attract additional capital for which the U.S. economy would pay only the world net-of-tax rate of return to capital. However the U.S. social benefits are equal to the gross of tax productivity of capital. On the other hand, Goulder, Shoven, and Whalley found that a world capital market may reduce the attractiveness of a consumption tax. In section III.5, we discuss some implications from the one-way capital flows assumed in the BT model.

3. Financial Behavior

The aspects of general equilibrium tax models discussed so far have highlighted their use in studying intersectoral distortions. Models with financial behavior may be used for analysis of three additional distortions caused by personal and corporate income taxes. These are inefficiency in portfolio allocation, in the choice between debt and equity finance, and in dividend payout rates.

The general equilibrium tradition has been to define a unit of capital as that which earns one dollar net of all taxes in any use. Feldstein and Slemrod (1980) pointed out, however, that the income tax system in the U.S. leads to differences in net-of-tax earnings from capital in different uses and for different owners. As an example, take two individuals in different tax brackets, each of whom owns an unincorporated business in the same industry. Their gross returns would be identical, but the individual in the lower income bracket would earn a higher net rate of return. Feldstein and Slemrod have shown, on the other hand that investment in the corporate sector is relatively more attractive -- compared to investment in the noncorporate sector -- for individuals in higher income brackets. It is relatively less attractive for lower income groups. Differences in these returns cause inefficiency in risk-bearing. In addition, because these two types of capital are observed to be held by both income groups, a comparison of expected rates of return is not sufficient to describe portfolio behavior. Slemrod has incorporated these observations in his model. Capital is measured according to stocks, not capital income. Individuals make their portfolio choices by balancing off expected net rates of return against variances in returns.

Modeling portfolio choice is useful in examining the effects of income tax integration. This reform would make the after-tax rates of return in the corporate and noncorporate sectors more equal. Because of the initial discrepancies in these rates for different income classes, the tax reform would cause different shifts in asset holdings by income class. This finding is discussed in section III.5.

Another application of general equilibrium tax models that is affected by portfolios is the study of the effects of inflation on capital allocation. The deductibilty of nominal interest payments from personal income tax liabilities provides a larger incentive for upper income groups to leverage their investments. Reforms such as indexing for inflation would lower inefficiency caused by this discriminatory incentive to bear risk.

Corporate financial behavior has been modeled by Slemrod and by Fullerton and Gordon. The corporate income tax encourages debt rather than equity finance because of the deductibility of interest payments on debt but not of payments to shareholders. The personal income tax system taxes capital gains and dividends differently. For most holders of corporate equity, capital gains are taxed more lightly. This encourages firms to retain earnings rather than paying out dividends.

Slemrod has modeled endogenous financial behavior by specifying that firms vary debt-equity ratios and dividend payout ratios in response to tax differentials. These response rates were taken from regression analysis. In his simulations of tax integration and indexing the distortions in financing behavior turned out to be of secondary importance relative to the distortions in portfolio behavior.

Fullerton and Gordon have proceeded differently. By examining the marginal after-tax returns to investors from debt and equity finance, they concluded that investors as a group could save on taxes by any increases in the firm's debt-capital ratio. Offsetting this tax advantage of debt, however, a higher debt-capital ratio would imply a higher probability of default. Thus they modeled the firm's financing decision as a tradeoff between tax advantages and bankruptcy costs. Their simulation results indicated that this distortion in debt-equity choices accounts for a large efficiency loss. Motivated by the uncertainty of economic explanations for dividend behavior, on the other hand, FG posited that dividend payout rates were immaterial by assuming that in equilibrium the firm must value a dollar of dividends at the margin the same as a dollar of retentions.

Although the addition of endogenous financial behavior has enriched the study of distortions resulting from income taxes, it has also added to data collection problems. For the United States, the last comprehensive study of asset behavior was the 1962 Federal Reserve Survey of Consumer Finances. These data do not provide information on how portfolios are allocated when there is high inflation. This is particularly unfortunate because one of the purposes of adding endogenous financial behavior is to measure how the interaction of nonindexed taxation of capital and high inflation has affected financial decisions. The importance of distortions to financial behavior, indicated by Slemrod and FG, however, supports continued modeling efforts in this direction.

4. Measurement of Effective Tax Rates

In modeling a country's tax code, there is the issue of whether average tax rates on income apply also at the margin. More generally, modelers face the problem of how to measure effective tax rates. These concerns arise both for the personal tax system and the corporate tax system.

Under a progressive personal income tax structure, marginal tax rates will be higher than average tax rates, and both will be higher at higher levels of income. To capture the progessivity of the personal income tax, some models (FSW, PW, Slemrod) treat the tax as a separate linear function of income for each household group. Under this treatment, however, each household faces a marginal tax rate that is unchanging even if simulations of a policy change show a redistribution of income. Slemrod (1982) has gone on to endogenize the marginal tax rate, a significant modeling improvement. In his model, households make portfolio choices on the basis of the real after-tax rate of return to each asset, as well as its riskiness. The taxable income from each asset depends on provisions such as the taxation of nominal instead of real gains, the use of historical cost depreciation, and the tax-exempt status of some bonds. Taxable income is determined on the basis of the assets that are selected by the household. It may also be affected by other aspects of the simulation that tend to redistribute income. In the end, the marginal tax rate is calculated by applying an approximation of actual tax tables to the household's computed taxable income.

There are further reasons why average and marginal personal income tax rates may differ. For example, transfer payments, through their eligibility requirements, may impose an implicit high marginal tax rate on labor income. The extent of tax evasion may vary with the level of marginal tax rates. These are propositions that have arisen in the economics literature, but which have not been included in the general equilibrium models covered in our survey.

It is possible to model differences in average and marginal household tax rates even apart from the income tax. For example, property tax payments and contributions to public pensions may be non-distorting to the extent that they are payments for benefits received from the government, in the form of local public services and retirement income, respectively. The Fullerton-Gordon model includes such treatment.

The measurement of marginal income tax rates for industries is, if anything, more problematic. All models with the exception of that of Fullerton and Gordon assume that the average tax rate on capital income in each sector applies also at the margin. In most cases, the industry's total observed tax paid is divided by observed capital income to obtain a tax rate for use in the producer's decision of whether to employ the next unit of capital.

This procedure greatly simplifies the data requirements as well as the model itself. Average tax rates provide a relatively simple and complete summary of the actual tax law. They capture the low tax payments attributable to investment tax credits, accelerated depreciation allowances, and depletion, and they capture the high tax payments attributable to insufficient depreciation allowances based on historical cost when there is inflation. Average tax rates also capture the effects of many complex details of the tax law, such as export subsidies, treatment of financial intermediaries, and possibilities for alternative accounting practices. In contrast, use of marginal tax rates requires explicit treatment of individual features of the tax code. In practice, therefore, marginal tax rates have provided a measure of the tax that might be expected by looking at a few major statutes. Because actual marginal tax rates are not observable, and because there are a variety of ways of incorporating a variety of features of the tax law, correct measurement of marginal tax rates has not been agreed upon.

The procedure of using observed tax rates as incentive tax rates, however, assumes away a number of reasons for why average and marginal tax rates might differ. First, the marginal investment may be financed by a composition of debt and equity which is different from the composition of previous investment. If these sources of finance are taxed differently, then the average and marginal investments are taxed differently. Second, unanticipated inflation reduces the real value of depreciation allowances on past investments without necessarily affecting the expected real value of depreciation allowances on the current marginal investment. Jorgenson and Sullivan (1981) argued that recent inflation rates have been higher than expected in the U.S., and have acted as a lump-sum tax on investments already in place. Third, the average tax rate mixes investments with different tax treatments. The FSW average tax rates from 1973, for example, include taxes paid on some investments that were made before the 1971 liberalization of depreciation allowances, while the marginal rate in 1973 should reflect only the then current law. Fourth, transitory or windfall profits on past investments are subject to the statutory corporate tax rate, while the expected normal return to the marginal investment is affected also by investment tax credits and accelerated depreciation allowances. Fifth, firms may have reasons unrelated to the marginal investment for using charitable decuctions, FIFO accounting, longer than minimum asset lives, and other features affecting the average tax rate without necessarily affecting the marginal tax rate. Finally, if some of the return to capital is treated as a risk premium, and if losses on the marginal investment can be used to offset profits on other investments, then the corporate tax can be viewed as risk sharing by the government. As such, at least part of the tax receipts would not reflect any marginal investment disincentives. Fullerton and Gordon have argued that marginal tax rates are considerably less than average tax rates for this reason.

Fullerton and Henderson (1981) estimated marginal tax rates for the 18 private industries of the FSW model, ignoring risk and using cost of capital formulas similar to those of Hall and Jorgenson (1967). Just the first five points above are sufficient to eliminate any similarity between the average tax rates and these marginal rates. Using different formulations of the average tax rates from Commerce Department data and different formulations of the marginal tax rates from cost of capital formulas, Fullerton and Henderson obtained correlation coefficients that varied around zero and never exceeded 0.3.

Fullerton and Gordon used a more complicated version of the same cost of capital approach. Noting that the 7 percent government bill rate in 1973 included some inflation risk if not default risk, they started with 5 percent as the nominal risk-free rate of return. Since the actual (and possibly expected) inflation rate was 6 percent, the real risk-free return may have been zero or negative. Thus the total return to equity is a risk premium and essentially all of the corporate tax becomes nondistorting. The tax is related to benefits in that, with full loss offsets, the tax payments are just proper compensation to government for accepting a fraction of the risk. It is perhaps not surprising that when FG simulated the removal of this corporate tax, together with a yield-preserving increase in the personal income tax (which distorts labor/leisure decisions at the margin), they found resultant welfare losses.

A couple of objections have been raised to this modeling. First, corporate profits in the United States have always been positive since the end of the Great Depression. If there is no significant risk of negative corporate profits, then at least some positive part of the return must be risk-free. This point really raises some inconsistencies among the various sets of data and available theories. For if some positive part of corporate profits is a real risk-free return, and if investors can arbitrage, then why would the government bill rate provide a zero or negative real return? Fullerton and Gordon reparameterized their model with a small positive risk-free return and obtained substantially the same results as before.

Second, Bulow and Summers (1982) came to conclusions that are very different from those of Fullerton and Gordon when they considered risk, corporate profits, and the corporate income tax. They argued that most of the investment risk is not in the income flow from the investment. Rather, it is from recapitalizations of that income stream, or changes in stock and bond prices that result in capital gains or losses to the investor. The corporate income tax does not offset these price changes. Depreciation allowances, for example, are not adjusted for _ex post_ changes in the value of the capital stock. Since these unexpected accrued capital gains are not subject to the same corporate tax rate, and unexpected accrued capital losses do not have the same loss offset, the FG story does not apply. The corporate tax does not reduce this important source of risk. Bulow and Summers concluded that the efficiency cost of the corporation income tax is close to what might be predicted from a model with marginal tax rates that are, on the whole, as high as average tax rates.

Our own conclusion, then, is that the FG model opens up the important possibility of different average and marginal tax rates. The data to implement that capability, however, are still subject to dispute.

5. Heterogeneity and Imperfect Mobility

Harberger introduced a framework in which capital and labor are each homogeneous, mobile across industries, and fixed in total supply. As general equilibrium models are increasingly applied to policy issues, this specification becomes less helpful in analyzing tax incidence, particularly over time. There has been relatively little improvement in this area, however, in the empirical general equilibrium models. The assumption that capital moves from industry to industry more quickly than it is added in the aggregate, for example, is a convenient though not compelling assumption in all the models. The PW model has households disaggregated by occupation, on the one hand, but, on the other hand, has labor being homogeneous and fully mobile in production. These examples of anomalous specifications should be viewed as temporary compromises along the path of development of these models. Some have modestly relaxed the homogeneity assumptions. Specifically, Keller has two different skill types for labor, Serra-Puche has both rural and urban labor, and BT include land as a separate factor of production.

In this section, we examine several attempts to relax assumptions of perfect mobility and homogeneity of factors. The examples here are quite diverse, and include problems of time and geography. Although introduction of constraints affects efficiency gains, we show that this type of innovation is particularly instructive in analyzing incidence.

There are two, very different studies that concern time constraints: AK's examination of rigidity of lifetime patterns of work and retirement, and Fullerton's (1982a) modeling of constraints in reallocation of capital across industries during finite time periods. The AK model has been applied to the study of replacement of an income tax by a wage tax and by a consumption tax. Their model traces the effects on 55 age cohorts, and is particularly insightful in tracing the effects on different cohorts in the transition to the steady state, which they estimate takes about 40 years. Because the wage and consumption tax structures would have different effects on workers as opposed to retirees, and because cohorts are not mobile between these two occupational categories, these taxes would impose different burdens on different cohorts. Retirees, for example, would be worse off under a consumption tax than under an income tax of equal yield in present value terms because the overall tax rate would have to be higher under the consumption tax. Conversely, retirees would be better off under the wage tax, since most of their income is derived from capital. On the other hand, some younger cohorts would lose in the transition to the steady state with a wage tax because their income loss from the tax rate increase is not fully offset in the short run by higher wages. In the long run, the higher capital-output ratios resulting from taxation of only labor income raise productivity and wage rates. Given that individuals are fixed in their pattern of work and retirement throughout their lives and given the infeasibility of levying age-specific taxes, AK found that the only way to obtain a Pareto-superior transition turns out to provide lower welfare gains for generations living in the post transition years than the consumption tax would provide.

The other study that explored imperfect mobility of factors is Fullerton's alternative specification of the FSW model. His application concerned imperfect mobility of capital between industries. Because existing capital was modeled as industry-specific, capital could not be observed to move out of an industry at a rate faster than its rate of depreciation. In other words, capital could increase in an industry only as a result of saving being greater than depreciation and could not be physically moved from one industry to another. This is perhaps an upper bound to capital immobility, since it takes no account of the moveability of items such as office equipment and trucks. Fullerton resimulated income tax integration under this specification and found that movement of capital out of several (largely noncorporate) industries was constrained. This implied a substantial reduction in efficiency gains in the first year, but not in subsequent years, when the constraint proved not to be binding.[15]

Another example of a heterogeneous capital stock is found in the BT model. Foreign-owned and domestically-owned capital were assumed to be perfect substitutes in production. Domestic capital was fixed in aggregate supply and totally mobile across industries within the country. The specification of the supply of foreign-owned capital to Canada proved to be a key factor in incidence results, however. In the BT model, foreign capital moves into Canada based on gross rates of return rather than net rates of return. This was justified because Canadian corporate income tax payments are credited in computing tax liabilities in the home country; as long as the Canadian rate is below the home country rate, it does not affect capital flows into Canada. As a result of these assumptions on capital supply, a substantial portion of the burden of an increase in the corporate income tax in Canada is shifted onto foreigners.

In yet another context, Slemrod found that inflexible supply of some assets affected tax burdens. He found that a fixed supply of tax-exempt debt, in conjunction with a particular model of portfolio choice, caused those whose income was above $50,000 to lose with the passage of tax integration. The logic is as follows. The corporation effectively shelters income for upper income groups, since the sum of the corporate income tax on a dollar of retained earnings plus the effective personal income tax on the resulting capital gains[16] is lower for them than the tax paid on a noncorporate investment, which is taxed at their (high) marginal personal income tax rate. For lower income households, the opposite it true: the tax rate on income from corporate capital is higher than from noncorporate capital. With the passage of integration, the upper income group would prefer to shift out of corporate capital because for them it would be taxed at a higher rate. In Slemrod's model, they were limited in their possibility to invest in alternative assets that are taxed at a rate below their ordinary personal income tax rate. Housing is less heavily taxed, but this group's Cobb-Douglas preferences for owner-occupied housing restricted them to spending a fixed proportion of their income on housing, and the price of housing did not fall enough for them to transfer their entire desired reduction of corporate holdings into housing. Another possibility was tax-exempt debt. They were not able to transfer their holdings into this asset because its supply was held constant by the government.

6. Dynamic Models

In this section, we discuss how factors of production have been allowed to grow over time. Of the models in our survey, only the AK, FSW, and FG models may be solved for a time sequence. In the AK model, each generation decides on its consumption and saving allocation for its entire lifetime, using perfect foresight expectations. Labor supply is exogenous.[17] The FSW and FG models have endogenous allocation over present and future consumption under myopic expectations, and allow the current period's saving to augment capital in the next period.[18] Labor supply depends endogenously on the after-tax wage rate. While the PW model is solved for only one period, two versions of it have, respectively, labor-leisure choice and saving behavior. The Serra-Puche model of Mexico also is a one period model with saving but has no labor-leisure choice. We discuss saving aspects of the latter models here because these features make them readily adaptable to solving a sequence of equilibria.

a. Labor-Leisure Choice

The approach to modeling labor-leisure choice in the FSW and the PW models is based on applying an average figure from the literature for the elasticity of labor supply with respect to the after-tax wage. While the implementation procedure appears to be straightforward, some of the assumptions that have to be made can affect the results.

In order to put this information into model-equivalent form, it is useful to look at the Slutsky equation in terms of labor supply elasticities:

$$\varepsilon_{Lw} = \varepsilon_{Lw}\Big|_{\bar{u}} + \frac{L}{E}\,\varepsilon_{LI}$$

where L = labor supply

w = net wage

E = endowment of labor

I = expanded income (wE)

ε_{Lw} = uncompensated elasticity of L with respect to w

ε_{LI} = income elasticity of L

$\varepsilon_{Lw}\big|_{\bar{u}}$ = compensated elasticity of L with respect to w

The compensated wage elasticity is positive, and the income elasticity is negative, so the uncompensated ε_{Lw} is of ambiguous sign.[19] Furthermore, if leisure is defined by $\ell = E - L$ then we have:

$$\varepsilon_{LI} = \frac{\partial L}{\partial I} \cdot \frac{I}{L} = \frac{\partial(E-\ell)}{\partial I} \cdot \frac{I}{E-\ell} = \frac{-\partial\ell}{\partial I} \cdot \frac{I}{\ell} \cdot \frac{\ell}{E-\ell} = -\varepsilon_{\ell I} \cdot \frac{\ell}{L} \quad .$$

In a CES utility function defined over leisure and consumption, for example, $\varepsilon_{\ell I}$ equals one and ε_{LI} would be $-\ell/L$. Thus

$$\varepsilon_{Lw} = \varepsilon_{Lw}\big|_{\bar{u}} - \frac{\ell}{E} \quad .$$

Now if the modeler uses a separately given estimate from the literature for the uncompensated elasticity ε_{Lw}, the compensated elasticity will vary directly with the postulated ℓ/E ratio. In the U.K. model, for example, PW suppose that the normal laborer supplies 40 hours out of a possible 50 hour work week, so ℓ/E is 1/5. In the U.S. model, FSW suppose a 40 hour week out of a possible 70 hour week, so ℓ/E is set at 3/7. Thus the FSW income elasticity for labor is -3/4 and the PW income elasticity for labor is -1/4. If the two models used the same exogeneous estimate for the uncompensated wage elasticity, then the FSW substitution effect (compensated wage elasticity) would be larger. For a zero uncompensated ε_{Lw}, for example, the compensated ε_{Lw} would be 3/7 and 1/5 for FSW and PW, respectively. Welfare costs depend on the compensated, not the uncompensated elasticity of labor supply. The algebra above helps to explain the relatively large labor-leisure distortions caused in the FSW and FG models when they raise taxes on labor to achieve the same total tax revenue after full integration. These labor-related welfare losses offset capital-related welfare gains in these simulations.

To measure the importance of alternative assumptions about labor endowments, we repeated the tax integration experiment summarized in Table 2, using a 50 hour maximum workweek in the FSW model. Under this assumption, integration of the corporate and personal income tax combined with restoration of a balanced government budget through upward scaling of income tax rates would produce a welfare gain of \$512.5 billion. This is substantially higher than the \$344.4 billion gain obtained earlier, with the assumption of a 70 hour potential workweek.

The procedure of taking an average elasticity is, of course, a shortcut alternative to specifying different labor supply elasticities and labor endowments by household groups. The literature on labor supply elasticities indicates that there are sharp differences in (uncompensated) elasticities between males and females, primary and secondary workers, and prime age and older workers (Hausman 1981). This implies a need to reconcile labor supply behavior of income groups with evidence based on demographic characteristics. There is already some - but arbitrary - specification of demographic differences in the PW model, where it is assumed that households headed by a retired or nonemployed person have no sensitivity to tax rates in making their labor supply decisions. The demographic data on households in this model in fact could be exploited more in this area. The benefits to differentiating the labor supply elasticities by income group would be important, for example, in evaluating proposals that affect lower-income households, such as introduction of a negative income tax or changes in transfer programs.

The importance of modeling labor-leisure choice (using average elasticities) appears to vary with the experiment being performed and the existing tax structure, as well as depending on the specification of labor and leisure endowments. PW simulated the effects of elimination of all tax and subsidy distortions in the U.K., with the revenue loss being made up by a broad-based sales tax. They reported only minimal differences in efficiency gains in simulations assuming, in turn, exogenous labor supply and a .125 elasticity of labor supply with respect to the after-tax wage rate. The labor-leisure distortion is apparently small compared to the the very large interindustry distortions in the U.K. tax system caused by indirect taxes, especially housing subsidies and differential sales taxes.

An alternative view of the importance of the labor-leisure choice may be seen in simulations of full integration of personal and corporate income taxes by Fullerton, King, Shoven, and Whalley (FKSW) (1981). Given an assumed labor supply elasticity of .15, FKSW found that the efficiency gain from integration when the yield preserving tax was multiplicative scaling of personal income tax rates was only one-half of that when a lump-sum tax was used.

b. Saving and Capital Formation

In the Serra-Puche, FSW, and PW models, saving is equivalent to the purchase of a fixed-weight bundle of capital goods. To simplify the computations, these models assume that the capital stock is augmented with a one-year lag. Thus, the FSW model computes a sequence of static equilibria rather than dynamic equilibria. (The Serra-Puche and PW models compute only one equilbrium rather than a series).

The specification of the mix of capital goods ignores composition effects, for example, between residential and non-residential investments. Residential investment would be produced largely by the construction industry, while nonresidential investment goods would be produced by the manufacturing sector.

Saving behavior in the Serra-Puche model is based on a fixed proportion of income. In the FSW and PW models, it is based on the expected return, assuming myopic predictions. Both models take as their central estimate Boskin's (1978) 0.4 elasticity, but simulate elasticities between 0 and 2 for sensitivity analysis. The importance of this elasticity had been pointed out by Feldstein (1974a). The PW model then approximates the elasticity of substitution between current and future consumption as 1 plus the saving elasticity, while in the FSW model, the relationship is solved explicitly.

PW found that the saving distortion is also a small factor compared to the largely intersectoral distortions of the British tax system.[20] They did find, however, fairly sizeable efficiency gains if the income tax were replaced by a pure consumption tax, particularly when there was inflation. The large response in saving in both simulations, however, suggests continued efficiency gains in the long run. The Fullerton, Shoven, Whalley (1982) study of the consumption tax in the U.S. also indicated potentially large efficiency gains. They showed huge sensitivity to the savings elasticity assumption, however.

The AK model has been used to examine the differential impacts of replacing the income tax by two taxes that eliminate the double taxation of saving, a consumption tax and a wage tax. Auerbach and Kotlikoff showed that, from the point of view of future generations, the consumption tax will be superior to the wage tax if, on average, wages are received earlier in life than consumption takes place. The utility differential was caused by the difference in the present value between these two streams of tax payments.

7. The Government Budget

In most models, the authors have assumed that the government budget is in balance. A tax reform that results in a revenue loss must therefore be matched by a tax increase or spending cut. In particular, a balanced budget is a necessary assumption in a model without assets, since deficits must be financed by an increase in government securities or by money creation.

The conventional wisdom in this field has been that the existence of a deficit does not change incidence or efficiency results. McLure (1970) has shown that in a Harberger-type model, allocation of resources depends only on relative prices, and not on absolute prices. General equilibrium models provide a solution only for relative prices; typically, the wage rate is taken as numeraire. Another equation is needed to close the model if absolute prices are to be derived. McLure illustrated his point by closing the model with the quantity equation for money. If a tax change is financed by money creation, this has no additional real effects on the economy, and therefore does not change economic decisions. The unimportance of financing effects does not carry over to a model with portfolio choice, however. Feldstein and Slemrod (1980) have shown, for example, that the corporate income tax may distort asset demand decisions even if it does not distort production decisions. Also, since the tax systems are generally non-neutral with respect to inflation, policies which affect absolute prices have allocational impacts. The potential for modeling unbalanced budgets is discussed below. First, however, we address the treatment of balancing the budget.

Budget balance in each period is a feature of all the models in the survey except the AK and Serra-Puche models, which have a government debt instrument. As shown in table 1, the revenue yield may be equalized by different taxes in different models. With the specification of the behavior of different consumer groups, the choice of the equal yield tax affects the efficiency and distributional results of the original policy change simulation. Financing by a consumption or broad-based sales tax usually introduces the least distortion of any available tax. An income tax should affect both labor-leisure choice and saving decisions, and may be more progressive.

The choice of a particular budget-balancing technique may in fact obscure the incidence of a particular tax proposal and limit the usefulness of a model. Although a lump-sum equal yield feature is not an option for policymakers, it may provide a useful benchmark for examining the incidence of a tax. Alternatively, several plausible equal yield options may be compared. An example that shows how the choice of a budget-balancing measure may limit the information from a model is found in the set of simulations that Keller has performed. In this model, government always has a balanced budget, but does not acquire the same yield. When a tax change increases government revenue, the additional funds are spent in the proportions that previous revenues were spent. This amounts to an increased demand for skilled labor, because this factor makes up a high proportion of observed government expenditures. Thus Keller's simulated tax increases - whether on commodities or labor - tend to raise the wage of skilled labor. This result stems only from the higher demand for skilled labor caused by the budget-balancing expenditures. Keller compared his model results with those from partial equilibrium studies, and attributed the differences to general equilibrium effects. This is a mistaken interpretation, since the partial equilibrium experiments did not include budget-balancing offsets to the tax changes.

Where a simulation measures not differential incidence but rather balanced budget incidence, it is important to model household preferences for public goods, in order to include the value of the change in government purchases in calculations of welfare change. This has been done by Keller, but not by Serra-Puche, despite his modeling of government expenditure policy to balance the budget.

The equal yield feature is important to consider in comparing simulation results across models. But it is also necessary to be aware of other features of the models in interpreting the effect of the equal yield tax. As one example, one may compare the results of tax integration of Slemrod and FKSW. When both made up revenue losses by multiplicative scaling of personal income tax rates, Slemrod's efficiency gains were much larger. Comparing the features of the models, one might conclude that the importance of modeling financing decisions, considered by Slemrod and not FKSW, is greater than other differences in specification that would lessen the relative estimate of efficiency gains of the Slemrod model. These latter differences include having fewer sectors and the specification of portfolio balance behavior. This conclusion would not be correct, however, because Slemrod did not have endogenous saving or labor supply responses, which FKSW had. In this case, the correct comparison of efficiency gain would use the FKSW simulation with a lump sum adjustment. When this is done, the results are in fact very similar.

In the AK model, the government budget constraint is that the present value of expenditures must equal the present value of revenue less the initial value of debt. (Financing by money creation is not an option.) Private and government capital are perfect substitutes in portfolios, but government debt is found to crowd out private capital formation. This phenomenon lowers potential efficiency gains when a tax reform is financed by issuing government bonds.

Introduction of money into the AK model would not be difficult on the supply side, since deficits are already a feature of the model. On the demand side, however, it would necessitate specifying portfolio decisions in a richer way. Since the model is not concerned with details of capital taxation, the distortionary effects of the inflationary impacts of money creation would not be extensive. A more promising model for this extention might be Slemrod's or Feltenstein's (1982). Serra-Puche's model has an initially unbalanced budget, and is being expanded to include monetary phenomena. Slemrod already has portfolio behavior, with money and debt as available assets. Debt of the Federal government would have to be separated from corporate debt in the data to model an unbalanced budget. Effective tax rates on capital are already a function of inflation, so that their specification would not be affected.

8. Technical Operations

This section describes three technical aspects of operating applied general equilibrium models: parameterization procedures, solution methods, and measurement of efficiency and distributional gains.

a. Parameterization

The paper for this conference by Ahsan Mansur and John Whalley goes into detail in describing existing methods for parameterizing general equilibrium models, and comparing these methods with stochastic estimation of parameters. Our discussion here is briefer, in light of their treatment of the subject, and because models do not differ greatly in this respect.

The primary behavioral equations in general equilibrium tax models are production and demand equations. Elasticities of substitution between factors or goods are usually selected from previous econometric studies. This means either that a range of parameters is used, corresponding to the range of estimated values, or that specific estimates are chosen from particular studies.

There are problems with this procedure that are often acknowledged by modelers themselves. First, estimates of parameters may vary from study to study. Generally there are no clear rules for deciding among alternatives. This problem is exacerbated by the unclear time frame of general equilibrium models. For example, although there seems to be a systematic difference between cross-section and time-series estimates of the elasticity of substitution between capital and labor, FSW and PW took an average of estimates from these two types of studies rather than choosing one or the other. A second problem is the lack of estimates of some parameters. Sometimes the model builders have used estimates for the same concept for a different country. Piggott and Whalley, for example, used estimates of savings elasticities for the U.S. in their model of the U.K. They compensated for this problem, however, by trying a wide range of estimates. At other times, the authors have estimated the missing parameters themselves. Fullerton and Gordon derived their own econometric estimates of parameters associated with bankruptcy costs. This was necessary because there is little empirical evidence on these costs.

When there is uncertainty about parameter values, the results are often subjected to sensitivity analysis, as described in several cases above. FSW (1978) reported experiments of the sensitivity of results to production elasticities in an early version of their model. They simulated elimination of the corporate income tax, varying the elasticity of substitution in production in all sectors from 0.5 to 2. In all cases consumers had Cobb-Douglas demands. For this experiment the welfare gain was almost exactly proportional to the production elasticity. PW (1982) have also reported sensitivities to both production and consumption elasticities. In both models the results indicate the importance of developing careful parameterization procedures.

Given exogenously determined substitution parameters, a technique of "backwards solution" has been used to determine the remaining parameters. For example, for CES production functions, FSW used outside studies to determine elasticities of substitution, then used benchmark data on labor and capital and assumed cost minimization under constant returns to scale to solve for the weighting parameter and the scale parameter. It must not be overlooked, however, that this is merely a calibration procedure used to match up the baseline solution with actual data. The backwards solution is a useful mechanical check on the programming of these models, but provides no assurance that the parameter estimates are reasonable. The residual parameters will take up the slack if there are errors in the substitution parameters. Also, even if the substitution elasticities are estimated correctly, but the production or consumption relationship is actually stochastic, the stochastic error for that period will show up in the residual parameters.

In fact, the choice of which parameters to make endogenous and exogenous is arbitrary, even though the results are not independent of the procedure selected. Authors have tried to follow the guideline of using outside estimates for scale-free parameters.

Another, less common, approach, is to let some of the data be the residual. Slemrod used this procedure because his backwards solution for the coefficient of risk aversion did not come close to existing estimates. Instead of using backwards solution for parameters, he solved backwards for risk premia that were implied by an exogenous risk aversion parameter. The fact that Slemrod chose this procedure is probably an indication of the non-robustness of the disaggregated data used in these models in general. Other authors (e.g, FSW) have noted the inconsistency of data, for example, on the sources and uses of income at a disaggregated level, and have arbitrarily selected some data as superior and adjusted other data to match.

Reporting sensitivity of model results to the adjustment of data has not been as common as reporting the sensitivity with respect to parameter selection.[21] Model builders should consider both experiments, however. One example where implications of data selection were shown was in the FG simulation of income tax integration. Fullerton and Gordon examined the results under two estimates of the risk-free rate of return. The ambiguity of this concept stemmed from the fact that short-term government debt is riskless in nominal terms, but not in real terms.

b. Solution Techniques

The Harberger model was solved by hand by taking linear approximations to production and consumption equations. Among the empirical models, this method is used for only the BT and Keller models. Because of the size of the matrices involved in these models, however, computation is done with the aid of a computer.

It is more common to use methods that properly handle large changes in tax rates. The remaining models are solved by three different techniques: a Newton-type method (PW), Gauss-Seidel iteration (AK, Slemrod), and a simplicial search method (FSW, Serra-Puche, and FG use Merrill's version of the Scarf algorithm).[22] In the case of the first two of these methods, successful convergence to an equilibrium depends in principle upon judicial selection of starting values and step size. Usually the benchmark values are used as starting values in alternate simulations. In fact, there have been no reports of cases, using these models, where there were convergence problems, or where alternative starting points have affected the answer.[23]

Comparative data on computation costs of these methods are not readily available. Even when the same model is solved using the same technique on different computers, there may be substantial differences in computation costs (see PW 1982). It is possible that different solution techniques are preferred for different models, but there is no evidence on this.

The costs of the Gauss-Seidel method depend on efficient ordering of equations into simultaneous and recursive blocks. We have not found any discussion of this in the applied general equilibrium literature, however. The cost of using simplicial search algorithms varies exponentially with the number of dimensions on the simplex. The FSW and FG models have three dimensions, corresponding to the price of labor, the price of capital, and the revenue yield. Other prices and, in the case of FG, yields on assets are solved for as functions of the prices on the simplex. The cost structure of these simplex algorithms is a deterrent to designing models with heterogeneous factors of production (see Fullerton 1982a). Future use of simplicial search methods will undoubtedly take advantage of innovations that reduce costs, such as the algorithm of vander Laan and Talman (1979). For the Newton method, Piggott and Whalley have reported that increasing the initial step size increases the efficiency of the search for the solution.

c. Measurement of Efficiency and Distributional Effects

In the Harberger model, the efficiency cost of capital taxation was measured by movement of capital. Since a unit of capital was defined as that which earns a dollar net of all taxes, this change in capital could be interpreted in income terms and compared to GNP. Incidence was measured by the change in the price of capital relative to the size of the tax. The computational general equilibrium models, on the other hand, measure welfare changes and their distribution among households in terms of income changes. In the case of the BT model, this is based on comparison of real incomes between the policy simulation and the baseline. When there is an explicit utility function generating demands, the comparison is based on the change in income that would compensate each household for the tax changes. As is well known from index number theory, compensating and equivalent variation provide bounds on the welfare change. These should both be computed. When the utility function includes leisure, as in FSW, the measure used is "expanded" national income, which adds the value of leisure time to monetary income.

Welfare changes are more complicated in a dynamic model. In FSW (1982), a present value calculation is used. This of course is sensitive to the assumption on the discount rate. In addition, FSW cautioned that present value welfare gains should be measured only for the initial population, so that the steady state growth rate does not distort the results.

Most models indicate distributional effects by measuring welfare changes for each household group. The PW model also calculates overall measures of the change in equality of incomes, such as the Gini coefficient.

IV. Conclusion

Computational general equilibrium models have proven useful in the area of long run analysis of alternative tax policies. A sizable number of studies have been completed examining policies such as a value-added tax, corporate and personal income tax integration, a consumption or expenditure tax, housing subsidies, and inflation indexation. We have surveyed several aspects of eight models and have found that they differ in structure in several areas. Clearly, researchers always face a tradeoff between simplicity and accuracy of detail, and in several areas (e.g., the level of disaggregation, the amount of substitution permitted) there is no "right" approach.

While we feel that the general equilibrium approach is very appropriate for analyzing large tax policy changes, there are a number of areas in which all existing models of this type could be improved. The first thing that strikes us in surveying the work in this field is that the profession still has not reached a consensus on the value of the few "key" elasticity parameters. First among these is the elasticity of labor supply. Our examination of the sensitivity of results to this parameter strongly underlines its importance. In disaggregated models, what are needed are labor supply functions by age, income, and possibly, marital status. The saving elasticity is probably the second most important parameter, at least for dynamic models. Again, disaggregated models call for these elasticities for each consumer class. Studies to date are far less conclusive on saving behavior than on labor supply.

The specification of the production side of the models could also be improved. While there is some agreement about the elasticity of substitution of primary factors, issues such as technical change (induced either by changes in relative prices or by inventions) and substitution possibilities among intermediate inputs are neither resolved nor for the most part incorporated in the models we survey. The models uniformly assume perfect competition and constant returns to scale. Clearly, these assumptions are made as convenient abstractions. Incorporation of imperfect competition and government regulation would be useful.

Two areas which some of these models have begun to address are dynamic response and the modeling of financial markets and behavior. The economy may take a substantial period of time to adjust to the types of tax policies which are analyzed with these models. The impact may discriminate between generations, and life cycle modeling may be appropriate. With dynamic models, the issue of uncertainty and expectations regarding the future must be addressed.

General equilibrium models have traditionally emphasized the real economy at the expense of analyzing financial markets. This approach is less than satisfactory for tax analysis where financial flows are being taxed in non-neutral ways. As we have described in this paper, several steps have been taken to include the modeling of financial behavior, but substantially more could be done in this area. Related to this is the treatment of government deficits. In order to handle adequately a government budget which is out of balance, a treatment of government bond markets is required. Our overall assessment is that both the areas of dynamics and financial behavior are ripe for further progress.

Finally, there are improvements which could be made in how the tax policies themselves are captured. For example, many of the models treat the personal income tax as a series of linear tax schedules. Higher income households may face higher marginal tax rates, but each faces a constant marginal tax rate. This fails to capture the fact that a policy such as integrating corporate income into the personal tax base would cause people to be pushed into higher marginal tax rate brackets. So, one area of possible improvement would be a more accurate modeling of the progressive rate structure of the personal income tax.

Another aspect of policy modeling which could be improved is in the expenditure of the tax receipts. None of the models has correctly included the implicit marginal tax rates of many income transfer programs or adequately captured the demand for public goods. To some extent, this failure has been alleviated by those models which compare only tax policies of equal revenue yield. The assumption is then made that the expenditure distortions are unaffected by the tax alternatives being considered.

We do not mean to conclude this paper on a negative note. Each of the models that we have surveyed is vastly richer than the two-by-two Harberger model from which they were derived. Empirical general equilibrium analysis has made great strides in the past decade and is now a useful tool for tax policy evaluation. We feel that these models can become even more valuable with further work and additional cross-fertilization between models under development.

Footnotes

1. This paper is not intended to survey all general equilibrium models related to taxation. Instead, we hope to learn about problems in designing a tax model by looking in depth at only a few of them. The choice of these eight models is ultimately arbitrary, however. By concentrating on nation-wide allocation effects of tax policy, in particular, we omit regional considerations and expenditure-side considerations. See, for example, Richter (1975) and Harrison and Kimball (1982). Other general equilibrium models include Dungan (1980), which simulates tax and expenditure changes in Canada, but which is primarily concerned with monetary policy, foreign exchange, and macroeconomic effects. Whalley (1980) describes a world model with four major trading blocs, while Boadway and Treddenick (1978) have a trade model of Canada. Aspects of trade, taxes, and development are addressed in models by Adelman and Robinson (1978) for Korea, Feltenstein (1980) for Argentina, de Melo (1978) for Columbia, and Dervis, de Melo, and Robinson (1981). Development models are described in Dervis, de Melo, and Robinson (1982).

2. The Rosenberg (1969) data and the aggregation by Harberger are discussed below.

3. The term "output effect" refers to the effect on the demand for the output of the industry where a factor of production is being taxed.

4. A version of the Ballentine-Thirsk model may be used to examine interregional incidence of taxation. This version is not reviewed here.

Footnotes (continued)

5. Except where otherwise specified, the description of the Fullerton-Shoven-Whalley model is applicable to the Fullerton-Gordon model as well. The FG model is discussed only where it differs from the FSW model.

6. In the earlier version, Slemrod (1980), agriculture was not distinguished from the corporate sector.

7. These choices do not necessarily indicate that industries have similar rates of substitution between factors. PW, for example, estimate production functions for the U.K. and derive quite varying elasticities which they use in sensitivity experiments. The "standard case" choices are based on average findings in the literature, a procedure that tends to minimize interindustry differences.

8. In such a plan, the corporate share price as a basis for capital gains purposes would be increased by the already taxed retained earnings.

9. If we look only at corporate income taxes and property taxes in Harberger's 1957 data from Rosenberg (1969), we see that these three industries did not have the lowest tax rates. Agriculture had the lowest rate, followed by crude petroleum, refined petroleum, and then the real estate sector. However, Harberger added imputations for the personal income tax on capital income from each sector. He assumed that 70 percent of net capital income in real estate was from untaxed imputed rents of owner-occupants, and that the other 30 percent from rental housing was taxed at a 20 percent personal rate. He assumed that farm income (net of other taxes) faced a 15 percent personal rate, but that crude petroleum income had depletion and similar privileges to offset any per-

Footnotes (continued)

sonal taxes. Finally, for all parts of the corporate sector, Harberger assumed a 20 percent effective rate which reflects a 40 percent personal tax on the half of earnings assumed to be distributed. Because refined petroleum was grouped with the corporate sector, Harberger's total tax on that industry was increased by personal taxes. The FSW model makes similar imputations for personal taxes of each sector, but these are based on the actual proportions of noncorporate earnings, retained corporate earnings, and distributed corporate earnings of each industry. In the 1973 data, petroleum refining starts with a low corporate rate due to depletion, and retains a low rate after personal tax imputations.

10. Harberger grouped his industries appropriately given his personal tax imputations. The other grouping is more appropriate given the 1973 data and FSW personal tax imputations.

11. We were not able to disaggregate real estate into owner-occupied and rental housing, as in the Slemrod model.

12. The median income for the U.K. was not provided in PW (1982).

13. This statement is less true for their "type III" households, which are composed of either two adults and more than one child, or of more than two adults. This group has significant labor income.

14. The first of four formulations in the Goulder, Shoven, Whalley (1982) paper has been added as a standard feature of the FSW model. The specification features: constant elasticity demand functions for foreigners' behavior, no Armington product heterogeneity, and no international capital flows. This ver-

Footnotes (continued)

sion of the FSW model was used in the simulations presented in Table 2. An earlier specification of the trade sector, also described in the Goulder, Shoven, Whalley article, was used in the previously published papers on the FSW model.

15. The constraints on movement of capital out of housing might be binding for a longer period of time if the low economic depreciation rates of Fullerton and Gordon (1982) were used.

16. This rate is reduced both by statutory preferential treatment and by deferral of realization.

17. In a very recent version of their model not available in time for this review, Auerbach and Kotlikoff have modeled labor-leisure decisions.

18. Recent work by Bovenberg and Keller (1981) has added a similar capability to Keller's model.

19. Estimates of ε_{LW} are generally zero or negative for prime age males and between zero and one for females and other groups. Fullerton (1982b) reviews thse estimates and finds .15 to be a plausible aggregate elasticity, but household differences here can warrant disaggregation on a basis other than income.

20. The modeling of the personal income tax also diminishes estimates of the distortion of saving decisions. The top income tax rate in the PW model is 30%, reflecting the proportional structure for most income levels. At high income levels, however, investment income is taxed at a higher marginal rate. This

Footnotes (continued)

feature of the tax system was ignored even for groups where it appears to be operative.

21. In some cases, tests of sensitivity to elasticity parameters may be interpreted as tests of data as well. In the case of labor supply, selection of labor supply elasticity and labor endowment affect the results in a similar manner. See section III. 6a for further discussion.

22. For a short description of gradient methods, including the Newton method and the Gauss-Seidel procedure, see Goldfeld and Quandt (1972). The Scarf algorithm is described briefly in Shoven and Whalley (1972, 1973), and in more detail in Scarf (1973). In their forthcoming book, Piggott and Whalley provide an excellent discussion of the Newton, Scarf, and Merrill techniques in applied general equilibrium models (Chapter 7).

23. Existence of a unique equilibrium depends upon the specification of the model, and testing for multiple equilibria is prudent, regardless of the solution technique. For discussion of models with multiple equilibria, see Kehoe (1980).

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