European Research Studies
Volume VI, Issue (3-4), 2003, pp. 177-205

Efficiency and Factor Reallocation Effects and Marginal Excess Burden of Taxes in the UK Economy[1]

Keshab Bhattarai [2]

Abstract

This paper analyses welfare impacts of tax reforms using a multisectoral general equilibrium tax model with multiple capital assets for the UK economy with micro-consistent benchmark data set for the year the 1995 received from the Inland Revenue. Households make consumption and labour leisure choices subject to their budget constraints, producers choose inputs to maximise profits. Prices adjust until demands equal supplies. Government revenue from the direct and indirect taxes finance public consumption and transfers.

Welfare gains from replacing existing capital income tax rates by a uniform 26.5 percent rate across sectors and assets are 0.035 percent of GDP (£219 million) in equal yield case, 0.28 percent of the GDP (1.8 billion) in no equal yield case. Tax induced changes in the relative prices of capital assets across sectors lead to reallocation of these assets among sectors. Producers tend to substitute capital for labour in agriculture, finance, public administration, and education sectors where capital inputs become relatively cheaper than labour inputs. Labour substitutes capital in manufacturing sector, where capital becomes relatively expensive after a uniform tax reform.

The marginal excess burden (MEB) of taxes varies according to the tax instruments in use, ranging from 35 pence in case of capital income taxes to 54 pence per pound of additional revenue from production taxes.

Keywords: general equilibrium, economic welfare, tax model, UK economy
JEL classifications: D5, D6, H2, H3

---

1 Major part of work for this paper was undertaken under an ESRC project on General Equilibrium and Dynamic Modelling for the Analysis of UK Policy Issues at the Warwick University. I am grateful to John Whalley at the universities of Warwick and Western Ontario [1] Major part of work for this paper was undertaken under an ESRC project on General Equilibrium and Dynamic Modelling for the Analysis of UK Policy Issues at the Warwick University. I am grateful to John Whalley at the universities of Warwick and Western Ontario for guidance and support for this research. I appreciate Graham Siddorn and Bill McNie at the Economics Unit of the Inland Revenue for data support and Tobi Kendall at Warwick for correcting the English. I acknowledge comments made by colleagues and participants of a seminar organised by the Centre for Economic Policy in Hull in May 2000. All errors and shortcomings are my own. Correspondence address: Economic Group, Business School, University of Hull, Faculty of Social Sciences, Cottingham Road HU6 7RX, Hull. K.R.Bhattarai@hull.ac.uk, phone: 44-1482-466483; fax: 44-1482-466216.

2 Economics Group, Business School, University of Hull, Cottingham Road, HU6 7RX, Hull

I. Introduction

Ratio of tax revenue to the GDP in the UK fell to 33 percent in 1992-93 from around 39 percent 1982/83 and is rising back to that level gradually in recent years. Direct tax instruments such as the labour income tax, national insurance contribution, and the council tax account for more than 50 percent of the tax revenue. Indirect sources that include value added tax (VAT), excise, corporate and other taxes make up the rest of it. While the government argues for new tax measures to raise the revenue to finance the increased demand for public services, there are genuine concerns about the rising and economy-wide distortionary impacts of these taxes. Which one of these tax instruments is the most efficient means of raising revenue? Which one of these has the least distortionary impact in the economy? How do these taxes affect the optimal choices of millions of households and firms in the economy? These are important questions of wide interest. A number of studies in the UK have tried to evaluate the impacts of taxes on labour supply and income distribution aspects in recent years using partial equilibrium approach (Giles and McCrae (TAXBEN:1983), Institute of Fiscal Studies (2002), Blundell-Duncan and Meghir (2002)). As the optimising consumers and producers shift the burden of taxes to other economic agents continuously until the demand and supplies equal in each market a general equilibrium approach is more appropriate method to measure these impacts of taxes. Partial equilibrium approach can significantly under or over estimate the impacts of taxes in the economy. An applied general equilibrium model can provide more accurate estimation of welfare by taking account of behaviour of households, firms, traders and the government while calculating the efficiency and resource allocation in the economy, which we aim to illustrate in this paper.

Applied general equilibrium models for tax policy analysis have been in use for almost four decades[3]. This paper outlines the specification, calibration, replication as well application of a 16 sector general equilibrium tax-policy model to evaluate the efficiency and factor reallocation impacts as well as the marginal excess burden of equal yield tax reform in the UK economy. It uses the benchmark data set for the year 1995 that were provided by the Economics Unit of the Inland Revenue as presented Tables A1 to A3 in the appendix.

This model has many features of a standard Arrow-Debreu general equilibrium model for an open economy (Arrow and Hahn (1971)). Households maximise utility subject to their budget constraints. Their consumption and labour supply decisions influence producers' choices, aimed at maximising profits subject to technology constraints. The equilibrium conditions imply that the markets for goods, labour and capital clear, firms receive zero profits in equilibrium, income is equal to expenditure for households, investors and government, and the value of exports

---

3 Some key references in applied general equilibrium models are Harberger (1959), Shoven and Whalley (1972, 1977, 1984,1992) Ballard-Fullerton-Shoven-Whalley (BFSW(1985)), Piggott and Whalley (1985),Taylor (1990), Robinson (1991), Mercinier and Srinivasan (1994), Rutherford (1997). The development of the mixed complementarity solution technique in 1990s, particularly with the GAMS/MPSGE software in recent years has made it easier to solve such large scale models (Brook, Kendrick and Meeraus (1992), Rutherford (1997), Dirkse and Ferris (1995, 1997)).

equals the value of imports. The government collects direct and indirect taxes from households on their income and consumption, production and capital income taxes from corporations, and import duties from traders. It spends revenue on public consumption or redistributes it as transfers to households.

Internal consistency of a general equilibrium model is assured when a model reproduces the benchmark data set, with calibrated model parameters, as its solution[4]. For each tax policy scenario, we compute changes in total money metric aggregate welfare by summing up money metric equivalent variations for households, investors and government. The money metric equivalent variation measures the amount of money required to compensate agents to move to the new equilibrium, from an old equilibrium with goods evaluated in terms of new prices.

II. Specification of the General Equilibrium Tax Model of the UK Economy

a. Household preferences, demand structure and technology

Utility of a representative household is assumed to be given by a CES function of leisure and composite consumption. A single household maximises utility, which is described by a nest of CES functions defined over composite consumption and leisure, subject to a budget constraint including a composite price for the commodity and leisure. The composite commodity demand is derived from these for sub-composite goods ($i = 1, ..., N$). Each of these sub composites is obtained from domestic and imported sources. At the top of the nest the utility function is written as

$$U = \left(\alpha C^{\varrho} + \beta L^{\varrho}\right)^{\frac{1}{\varrho}} \tag{1}$$

where U is the utility of household, C is the consumption of the composite good, L is the leisure taken by the household, α is the share of full income of household spent on consumption of the composite good, β is the share of full income spent on leisure, and ϱ is the elasticity parameter in the utility function; the elasticity of substitution between goods (and leisure) being equal to $\sigma = \dfrac{1}{1-\varrho}$.

[4] Technically there are five steps in the numerical implementation of a general equilibrium model: benchmarking, model declaration, benchmark replication, counterfactual solution and report writing. Model dimensions (sets) are declared and all base year data are read in tabular, parameter or scalar form in the base year model. Then modellers specify markets, production activities and budget constraints for each agent in the model declaration part. This part consist of blocks of equations for production technology, household preferences, revenues and income constraints. A model is calibrated when the base year data is reproduced by the model as its solution. This step is known as benchmark replication. In the fourth step various taxes or exogenous variables are changed in order to assess the efficiency and allocation effects of proposed changes in tax rates or transfers. Finally, model solutions are printed for review in the reporting stage. The MPSGE code is very concise for a standard Arrow-Debreu model.

The household receives income from capital and labour endowments, and transfers from the government, paying taxes on household and capital income. The disposable income of a household is given by

$$H = \sum_j \sum_i r_j (1 - t_{j,i}) \theta_{j,i} \overline{K}_j + (1 - t_l) w\overline{L} + TR \tag{2}$$

where H is the income, $\theta_{i,j}$ is the share of type j asset used in sector i, $\overline{K}_j$ is the endowment of capital type j for the household, $\overline{L}$ is the endowment of labour, TR are the transfers received, r is the rental rate of capital by type j, w is the wage rate, t_l is the tax rate on labour income[5], and $t_{j,i}$ is the tax rate in sector i on rental income from capital of type j.

$$P(1 + t_v)C + w(1 - t_l)L = H \tag{3}$$

where P and C are prices and quantities of composite goods respectively, and t_v is the effective tax rate on consumption; consisting of tariffs, duties and levies, value added taxes and subsidies.

The demand functions for goods and leisure are obtained by maximising (1) with respect to (2) and (3), and take the following form

$$C = \left(\frac{\alpha H}{(P(1+t_v))^{1-\sigma} \left(\alpha (P(1+t_v)))^{1-\sigma} + \beta (w(1-t_l))^{1-\sigma} \right)} \right) \tag{4}$$

Consumption of leisure is given by

$$L = \left(\frac{\beta H}{(w(1-t_l))^{1-\sigma} \left(\alpha (P(1+t_v)))^{1-\sigma} + \beta (w(1-t_l))^{1-\sigma} \right)} \right) \tag{5}$$

In the one household case, the labour supply of each household LS is given by the difference between the household labour endowment, and the demand for leisure, L.

$$LS = \overline{L} - L \tag{6}$$

In equilibrium, the labour supplied by the household must be consistent with the total demand for labour derived from the profit maximising behaviour of firms (as set out in the following section).

Composite consumption covers N sub-composite goods in the model,

$$C = \psi \left(\sum_i \delta_i^c CC_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{7}$$

[5] The effect of tax distortions on the labour-leisure choice can be captured through a subsidy to the consumption of leisure at rate t_l.

where CC_i is the ith good composite of domestic and imported consumption goods, ψ is the unit parameter of the CES composite function and δ_i^c is the share of the consumption good. The overall value of composite consumption should satisfy:

$$P \cdot C = \sum_i P_i \cdot CC_i \qquad \text{for } i = 1, ..., N \quad (8)$$

The term P is the price of composite consumption net of indirect taxes, and CC_i is composite consumption good of both domestic and import of the ith good.

International Trade

The total supply, A_i, for each sector is produced using domestic and imported goods, and is given by a CES Armington (1969) function as following:

$$A_i = \Phi\left((1-\delta_i^m)D_i^{\frac{\sigma_m-1}{\sigma_m}} + \delta_i^m M_i^{\frac{\sigma_m-1}{\sigma_m}}\right)^{\frac{\sigma_m}{\sigma_m-1}} \quad (9)$$

where A_i is the CES aggregate of domestic supplies D_i and import supplies M_i. δ_i^d is the share of domestic supplies for good i, and δ_i^m is the share of imports in good i, σ_m is the elasticity of substitution in the aggregate supply function, and Φ is the shift parameter of the aggregate supply function. Overall market clearing in the product market implies that

$$A_i = CC_i + G_i + I_i \quad (10)$$

where G_i and I_i represent composite consumption by the government and investment respectively (discussed below). In value terms,

$$PA_i A_i = PD_i D_i + PM_i M_i \quad (11)$$

where D_i and M_i are domestic and import supplies at prices PD_i and PM_i respectively, and PA_i is the price of total supply in sector i.

In the above equation, domestic supply, D_i, is the part of the output sold in the domestic market. The rest of domestic output is sold abroad, and given by the product transformation function.

$$Y_i = \Theta\left((1-\delta_i^e)D_i^{\frac{\sigma_y-1}{\sigma_y}} + \delta_i^e E_i^{\frac{\sigma_y-1}{\sigma_y}}\right)^{\frac{\sigma_y}{\sigma_y-1}} \quad (12)$$

where E_i is exports, D_i is domestic supplies, σ_y is the elasticity of substitution in total supplies, δ_i^e is the share of exports, and Θ is the shift parameter in the production function. The total value of gross domestic product is composed of value of domestic sales and exports.

$$PY_i Y_i = PD_i Y_i + PE_i E_i \quad (13)$$

The value of exports is equal to the value of imports in equilibrium.

$$\sum_i PE_i E_i = \sum_i PM_i M_i \qquad (14)$$

where PE_i and PM_i are the world prices of exported and imported commodities in terms of the numeraire. These import and export prices could be different than the domestic prices because of differentiation between domestic and foreign products in this model. Gross of export tax or tariff prices of domestic commodities tends to be close to the world prices as the elasticity of transformation between domestic sales and exports and elasticity of substitution between domestic supplies and import reach to the infinity.

Production

Producers use labour and capital in each of N sectors to yield value added. This also is given by CES functions.

$$VA_i = \Omega_i \left((1-\delta_i)(K_i)^{\gamma_i} + \delta_i (LS_i)^{\gamma_i}\right)^{\frac{1}{\gamma_i}} \qquad (15)$$

where VA_i is the gross value added of sector i, Ω_i is a shift parameter in the production function, K_i and LS_i are the amounts of capital and labour used in sector i, δ_i is the share parameter of labour in the CES function, and γ_i is the CES factor substitution parameter.

The gross output of each sector Y_i contains value added, VA_i and intermediate inputs. We allow substitution between domestic and imported intermediate inputs, and between value added and intermediate inputs.

$$PY_i Y_i = PV_i VA_i + \sum_j PA_i (1+t_{i,j}^d) DI_{i,j} + \sum_j PM_i (1+t_{i,j}^m) MI_{i,j} \qquad (16)$$

where $DI_{i,j}$ is the demand for domestic intermediate input and $MI_{i,j}$ is demand for imported intermediate inputs, PV_i is the composite price of value added, and VA_i is the value added component of gross output, $t_{i,j}^d$ and $t_{i,j}^m$ are taxes on intermediate demands.

At any set of prices, producers in each sector maximise profits subject to their technology constraint

$$\Pi_i = PY_i Y_i - wL_i - \sum_{j,i} r_j K_{j,i} - \sum_j PA_j (1+t_{i,j}^m) MI_{j,i} - \sum_j PA_j (1+t_{i,j}^d) DI_{j,i} \qquad (17)$$

where Π_i is the profit of sector i. In equilibrium, factor demands by sectors are determined where the value of the marginal product of factors equal factor prices, and there are no positive profits for producers.

b. Treatment of the public sector

Government Budget

The government collects revenue from taxes on capital and labour income and value-added taxes on final demand, production taxes on intermediate inputs, and tariffs on imports. All tax revenues collected are either used to purchase public goods or transferred to households in lump sum form; ie.

$$G + TR = \sum_j \sum_i t^k_{j,i} r_j K_{j,i} + \sum_i t^{vc}_i P_i CC_i + \sum_i t^{vg}_i P_i G_i + \sum_i t^{vk}_i P_i I_i + \sum_i t_l wLS + \\ + \sum_i t^m_i M_i + \sum_j \sum_i PA_j t^m_{i,j} MI_{j,ii} + \sum_j \sum_i PA_j t^d_{i,j} DI_{j,ii} \qquad (18)$$

where G is public consumption, and $t^k_{i,j}$ is the tax rate on capital income from asset j used in sector i. These rates are taken from P-Tax formulae. There are four different indirect taxes in the model: tariffs, duties and levies, VAT and subsidies. t^{vc}_i is the effective ad valorem tax rate on final consumption of households, t^{vg}_i is effective indirect tax rate on public consumption and t^{vk}_i is effective tax rate on investment. t_l is the tax rate on labour income, and t^m_i is the tariff on imports, $t^d_{i,j}$ and $t^m_{i,j}$ are taxes on intermediate demands.

These taxes, particularly when they are levied at different rates on different sectors and households, have distortionary impacts on the allocation of resources in the economy. These are captured by the model. The value of government consumption is given by:

$$G = \sum_i PA_i GD_i + \sum_i PA_i GM_i \qquad (19)$$

where GD_i is government consumption of domestic goods and GM_i is government consumption of imported goods.

c. Model closures and savings and investment

Total investment demand I equals the use of investment goods from domestic and imported sources.

$$I = \sum_i PA_i ID_i + \sum_i PA_i IM_i \qquad (20)$$

where ID_i is investment demand for domestic good i, and IM_i is investment demand for imported good i. The savings-investment identity closes this model where I is the gross of indirect taxes.

We have taken a closed capital market view until so far. This essentially means the allocation of assets across sectors sums up to the domestic endowments of assets which implies:

$$\bar{K}_j = \sum_i K_{i,j} \qquad j = 1, ..., 5 \qquad (21)$$

where $\bar{K}_j$ is the endowment of jth type of asset and $K_{i,j}$ allocation of type j asset in sector i. Reallocation occurs until the rental rate of capital is same across all sectors.

The closed capital market assumption is not realistic for the UK economy, where capital freely moves according to domestic and foreign rate of returns. More realistically

$$\bar{K}_j + FK_j = \sum_i K_{i,j} \tag{22}$$

where FK_j represents net inflow or outflow of asset type j. The inflow and outflow of capital asset depends upon the gap between the rental rate in the UK and the Rest of the World.

$$r_j^{UK} \geq r_j^{w} \Rightarrow FK_j \geq 0 \tag{23}$$

$$r_j^{UK} \leq r_j^{w} \Rightarrow FK_j \leq 0 \tag{24}$$

where r_j^{UK} is the net of tax return in asset j in the UK and r_j^{w} is the net return in the world market. Thus the amount of inflow or outflow depends upon the gap between the domestic and world rental rate of capital. Capital asset movement occurs until this gap is eliminated.

d. Model Equilibrium Conditions and Closure

In this model a competitive equilibrium is given by prices of consumption goods, P_i; the rental rate of capital assets r_j; a wage rate for labour, w; levels of gross output, Y_i (gross of intermediate use); capital use, K_i; and sectoral use of labour, L_i; imports M_i, exports X_i, intermediate inputs $INT_{i,j}$, investment I_i, government consumption G_i, private consumption C_i, such that,

i) The markets for goods and services, labour and capital clear; and
ii) budget constraints of households, the government and investors are satisfied.

More specifically, the market clearing condition for the goods market is given by

$$X_{i,t} = \sum_{h=1}^{3} C_{i,h,t} + I_{i,t} + GD_{i,t} + INT_{i,t} + DST_{i,t} + TD_{i,t}. \tag{25}$$

where $F_i^d = C_i^d + I_i^d + G_i^d + E_i^d$ is a decomposition of final demand into household consumption, investment, and government consumption, $INT_{i,t} = \sum_j (IO_{i,j,t} * XD_{j,t})$ is total intermediate demand, and $a_{i,j}^d$ is sector i input per unit of sector j output.

$$M_i = F_i^m + \sum_{j=1}^{N} a_{ij}^m Y_j \tag{26}$$

where $F_i^m = C_i^m + I_i^m + G_i^m + E_i^m$ represents a decomposition of final demand for imports and $INT_{i,t} = \sum_j (IO_{i,j,t} * XD_{j,t})$ is total imports for intermediate inputs.

The capital market clearing condition, in the closed capital market case, implies

$$\bar{K}_j = \sum_i K_{i,j} \quad j = 1, ..., 5 \tag{27}$$

The capital market clearing condition in the open capital market scenario implies

$$\bar{K}_j + FK_j = \sum_i K_{i,j} \tag{28}$$

and labour market clearing implies:

$$LS = \sum_i LS_i \tag{29}$$

where LD_i represents labour demand in the ith sector. We have not considered mobility of labour to and from the UK economy explicitly in this model.

When there are n different markets in the economy, relative prices that clear n–1 markets clear the nth market as well. Because of the complexity of the model, analytical solutions are difficult to find, therefore it needs to be solved by a numerical technique.

We use the Hicksian equivalent variation (*EV*) and compensating variations (*CV*) to measure welfare gain or loss between a benchmark and counterfactual tax reform scenarios. A general rule of thumb is that a positive Hicksian *EV*, as a result of reduction in tax rates, is a measure of welfare gain, and corresponds to a negative Hicksian *CV*, which gives the amount of money to be taken away from the consumer in order to keep her at the old utility level. *EV* measure uses benchmark (old) prices to compute the money metric measure of utility while the *CV* measure uses new prices. As Shoven and Whalley (1992) present it, the *EV* and *CV* measures of money metric utility between a benchmark and counterfactual scenarios can be computed as following:

$$EV = E(U^N, P^0) - E(U^0, P^0) \tag{30}$$

$$CV = E(U^N, P^N) - E(U^0, P^N) \tag{31}$$

superscripts *N* and *O* represent new and old values of the variable on which they appear, and *E* is money metric utility, *U* the utility *P* the price level. If utility functions are linear homogeneous then the original and the new equilibria can be thought of in terms of a radial expansion in the utility surface. Therefore the change in welfare between benchmark and counterfactual solutions of the model is proportional to the change in income or the percentage change along the radial projection between two consumption points. A positive *EV* represents a gain compared to the old equilibrium and a negative *EV* represents a loss. For each tax reform scenario we express *EV* as a percentage of the UK GDP for the benchmark year. Then we check the robustness of the model results by computing the sensitivity of the *EV*/GDP ratio to a set of relevant substitution elasticities in consumption and production.

Numerical technique is used to solve the model as the analytical solutions for such model with 1462 variables and equations is very complex and almost impossible to derive in algebraic form.

III. Efficiency and Reallocation Impacts of Capital Income and Indirect Tax Reform

The major focus of this section is on evaluating the impacts of capital income taxes using the model outlined in the previous section using the base year tax rates as given in Table A4 and A5. We use the model mainly to assess the impacts of taxes on five types of capital assets, labour income taxes and four types of indirect taxes. The five types of capital assets are buildings, short and long lived plant and machinery, vehicles and dwellings; the four types of indirect taxes are import duties, subsidies, duties and levies and value added taxes on intermediate and final demands.

First, we consider four different scenarios to assess the impact of capital income taxes on the economy. These scenarios consist of moving to a uniform yield preserving 26.5 percent tax rate from the existing taxes for central and unit elasticity cases, and moving to a uniform 30 percent tax rate from the existing taxes without any equal yield requirements for low and high labour elasticity cases. The robustness of each of these experiments is checked by using model solutions for low (0.15) and high (0.3) values of labour supply elasticity. For each of these scenarios, we compute changes in total money metric aggregate welfare for the economy by summing up money metric equivalent variations for households, investors and the government. To be comprehensive, we take percentage changes in total money metric equivalent variations as a percentage of UK GDP for various alternative capital tax arrangements. Then we check the robustness of the model results by computing the sensitivity of the EV/GDP ratios of tax reforms for sets of substitution elasticities between capital and labour and among capital assets. This section also covers a short description of the effects of tax policy changes on the reallocation of capital assets and labour across sectors and their effects on output.

We then present the marginal excess burdens of capital income taxes based on model solutions, followed by a brief summary of model results for reform in other indirect taxes and the replacement of household income taxes by lump sum taxes.

a. Efficiency effects of tax reform

We present a summary of results of capital income tax reform under four different scenarios in Table 1. The two scenarios in case A show welfare gains when capital income tax rates existing in 1995 (see Table A4) are replaced by a uniform 26.5 percent rate across sectors and assets for a low labour supply elasticity. In the central case, we find an improvement in efficiency of 0.035 percent of UK GDP (£219 million in terms of 1995 prices) Note that the gross value added was 628 billion as given in the input-output table in A2. The improvement is 0.022 percent of UK GDP (£139 million) in the case of unit elasticity specification.

Table 1: *Aggregate Welfare Results of Replacing Capital Income Taxes By Uniform Rates in Equal and No-equal-yield Cases (with labour supply elasticity of 0.15)*

A. Equal Yield Case

Tax Experiments	Hicksian equivalent variation as % of GDP	Hicksian compensating variation as % of GDP
Replacing the Existing Capital Income Taxes By Yield Preserving Uniform Rates (Central case)	0.035	–0.036
Replacing the Existing Capital Income Taxes By Yield Preserving Uniform Rates (Unit elasticity case)	0.022	–0.022

B. No equal yield central elasticity case with low and high labour supply elasticities

Tax experiments	Hicksian equivalent variation as % of GDP	Hicksian compensating variation as % of GDP
Replacing the Existing Capital Income Taxes By Uniform Rates (Low case)	0. 281	–0.279
Replacing the Existing Capital Income Taxes By Uniform Rates (High case)	0.283	–0.281

Note: See section 4 for numerical values of substitution elasticities in central and unit cases.

We relax the equal yield requirement in the no equal yield scenarios, in Cases B of Table 1. The size of government can, and usually does, change after the tax reform without any adjustment to other taxes. The efficiency gain from replacing existing taxes by uniform capital income tax rates in the no equal yield capital tax reform was about 0.281 percent of UK GDP (1.8 billion pounds) for the low labour supply elasticity case and 0.283 percent for the high labour supply elasticity.

In an earlier version of the model, the computed efficiency gain from replacing capital income tax by yield preserving lump-sum taxes was 0.3 percent of the UK GDP.

The improvement in aggregate efficiency reported here reflects removal of distortions existing in the economy by introducing uniform tax rates on capital. We have checked robustness of these results with respect to high and low labour supply elasticities. These results are lower than those reported in Piggot and Whalley (1985) and Shoven and Whalley (1992) mainly because the benchmark year 1995 had already witnessed significant amount of tax reform compared to the benchmark taxes in their studies.

b. Sensitivity analysis of model results

We check the robustness of the welfare impact results outlined above by means of sensitivity analysis of the results to four different sets of substitution elasticities among assets (σ_k), keeping elasticities of substitution between labour and capital (σ_v) fixed; and four different sets of elasticities of substitution between labour and capital, keeping substitution elasticities among assets fixed. Table 2 includes the results of sensitivity analysis for replacing the existing level of capital income taxes by yield preserving uniform capital income tax rates, for both low and high labour supply elasticities.

For all pairs of elasticities, the welfare impacts of moving to a yield preserving capital income tax from a set of existing taxes is positive and almost linear in the value of substitution elasticities among assets, for a particular set of elasticities of substitution between labour and capital assets. Similarly, it is also almost linear in the values of substitution elasticities between capital and labour for any particular value of substitution elasticities among capital assets.

Table 2: *Sensitivity of aggregate welfare as a percentage of UK GDP to substitution elasticities between capital and labour, and to substitution elasticities across capital assets*

A. Labour supply elasticity 0.15

σ_v \ σ_k	**0.75**	**1.0**	**3.0**	**5.0**
0.75	0.01513	0.01705	0.0316	0.04594
1.0	0.01951	0.0223	0.03607	0.05046
3.0	0.04999	0.05252	0.06898	0.08426
5.0	0.07694	0.08039	0.09992	0.11647

B. Labour supply elasticity 0.3

σ_v \ σ_k	**0.75**	**1.0**	**3.0**	**5.0**
0.75	0.01496	0.01688	0.03143	0.04576
1.0	0.0193	0.02124	0.03587	0.05026
3.0	0.04947	0.05206	0.06866	0.08399
5.0	0.07616	0.07971	0.09953	0.11618

Note: *σ_v is the elasticity of substitution between capital and labour*
σ_k is the elasticity of substitution among capital assets.

When both σ_v and σ_k are very high, each assuming a value of 5.0, the welfare impact of switching to a uniform tax rate was about 0.11 percent of UK GDP, which amounts to nearly £691 million.

c. Reallocation of capital assets and labour in production

Firms use capital and labour services in production. Following convention in general equilibrium analysis, before tax prices of these factors are set to unity in the benchmark. Producers, or users of these inputs, however, pay the gross of tax prices but the owners of these factors receive net of tax payments. Government collects the tax revenue. In this model capital income taxes are collected at the sectoral level. The labour tax does not differ by sector and is collected from households[6].

In 15 out of 16 sectors, capital services are split between four different assets: buildings, short lived plant and machinery, long lived plant and machinery, and vehicles. Labour is homogeneous across all these sectors. The housing services sector is peculiar in terms of input use, as it uses dwellings as its only input. It uses none of the other assets nor any labour. Housing sector is isolated from other sectors.

Table 3: *Capital Asset Reallocation from Equal Yield Replacement of Capital Income Taxes by Uniform Tax Rates By Industry (% Change in Capital Use (By Asset By Sector)*

a. Central Case elasticity specification				**b. Unit elasticity specification**					
Asset Class	**Build-ings**	**PM Long**	**PM Short**	**Vehi-cles**	**Asset Class**	**Build-ings**	**PM Long**	**PM Short**	**Vehi-cles**
Agric	2.05		2.76	–5.3	Agric	2.1		2.17	–4.63
Extr	21.17	–0.45	10.26	2.11	Extr	16.21	2.46	9.15	4.06
Min	–1.47		0.3	2.49	Min	–0.6		0.09	1.46
Chem	–8.98	–0.52	–5.79	7.88	Chem	–5.15	–0.46	–3.63	4.58
Metal	–11.62	–4.93	–9.55	4.81	Metal	–7.29	–3.53	–6.41	2.54
Eng	–12.06	–5.88	–8.12	3.06	Eng	–8.76	–5.05	–6.51	0.92
Food	–5.87	–1.08	–3.72	4.64	Food	–5.51	–1.24	–3.82	4.52
OTHMA	–6.74	–1.97	–3.45	4.24	OTHMA	–7.04	–2.28	–3.85	4.69
Power	–6.26	0.38	20.12	6.89	Power	–3.96	–0.02	12.92	4.29
Constr	–8.31	–1.15	0.85	1.92	Constr	–7.91	–1.23	0.86	1.86
Distr	–10.82	–1.66	4.68	5.63	Distr	–6.6	–1.24	2.82	3.31
Trans	–11.56	3.34	9.65	–1.03	Trans	–7	1.99	5.97	–0.76
Fin	14.18	–8.78	–1.34	–2.01	Fin	9.42	–5.6	–0.73	–1.25
PubAD	18.89	–5.02	0.91	2.03	PubAD	12.12	–3.27	0.58	1.19
EducA	20.89		–2.55	1.96	EducA	13.39		–1.54	1.22

Note: The capital income tax rates used here may be different from the capital income tax rates in use in the Inland Revenue.

Equal yield uniform capital tax rate 26.5%

Aggregate Welfare Effect: £218.1 mill (95) = 0.0347% of UK 1995 GDP

Aggregate Welfare Effect: +£140 mill (95) = 0.0223% of UK 1995 GDP

[6] Though social security, national insurance contributions could be thought of as taxes on labour use.

The relative prices of capital assets differ across sectors in the benchmark, mainly for the reason that capital income tax rates differ by assets and sectors. The equal yield uniform tax reform reduces these inter-sectoral and inter-asset differences in the relative user cost of capital in the counterfactual scenarios. Consequently we see a significant reallocation of capital and labour resources across sectors occurring in comparison to the base year.

The capital reallocation results in Table 3 show intra-asset reallocation of capital assets with the central case elasticity specification for both low and high labour supply elasticity cases. The model results confirm our assertion about the reallocation effects of changes in the relative prices. Based on changes in relative prices of capital between sectors, we expect more use of building type assets in the agriculture, extraction, financial services, public administration and education sectors. The relative prices of building type assets decrease in these sectors when capital income taxes become uniform across sectors and assets, compared to the benchmark relative prices. The sector-by-sector results in the first row in Table 3 show that in the case of low labour supply elasticity, reallocation is actually happening in our model solutions. The use of building type assets increases by 21 percent in education, 19 percent in public administration, 21 percent in extraction, 14 percent in financial services, and around 2 percent in the agriculture sector. The use of buildings decreases in the other sectors because of a rise in the relative price of building assets in those sectors compared to the base year.

The reallocation results for other assets, long and short lived plant and machinery and vehicles could also be interpreted in this manner. We see positive changes in the use of a particular asset in which the user cost of the asset has reduced relative to the base year.

Besides inter-sectoral reallocation, we also see inter-asset substitution and capital labour reallocation after the uniform tax reform. Given that we have a fixed endowment of each type of capital asset in both the benchmark and the counterfactual scenarios, total reallocation is subject to this capital stock constraint.

Table 4: *% Changes in Employment and Output Equal Yield Replacement of Capital Income Taxes By Uniform Tax Rates (Central case specification of elasticities)*

Industry	Labour supply elasticity 0.15	
	% change in employment (labour use)	**% change in output**
Agric	–0.989	–0.065
Extra	–0.843	1.606
Minin	–0.207	–0.367
Chemi	4.758	–0.251
Metal	1.850	–0.731
Engin	0.352	–0.970
Food	2.797	–0.044

Othma	0.951	–0.241
Power	4.084	–0.262
Constr	0.130	–0.040
Distr	2.673	–0.121
Trans	1.818	–0.015
Finan	–4.757	0.124
PubAD	–0.827	0.035
EducA	–0.897	0.107
House		0.01

Reallocation between asset types also occurs when the relative prices of these assets change in counterfactual scenarios. Inter-asset reallocation in response to capital tax reform is reflected in terms of positive changes for some assets, followed by negative changes in the use of other assets within a sector. For every sector, some assets change positively and some other assets change negatively in response to the uniform tax reform. For instance, in the agriculture sector, use of the buildings type asset increases by 2 percent, use of plant and machinery with short life also increases by 2.8 percent, while there is a reduction of 5.3 percent in the use of vehicle type assets.

The capital reallocation effect explained in this section is sensitive to elasticity configurations. We consider a unit elasticity case in Table 3.b. Generally the direction of changes in the allocation of assets is the same as in the central elasticity specification outlined in Table 3, while the magnitude of such changes is smaller for the unit elasticity specification than in the central elasticity specification.

Besides inter-sectoral and inter-asset redistribution, changes in the relative user cost of capital have a significant effect on the use of labour across sectors. When capital inputs become relatively cheaper than the labour input, producers tend to substitute capital for labour. As outlined above, capital becomes relatively cheaper in certain sectors such as agriculture, finance, public administration, and education, and relatively expensive in some other sectors, particularly manufacturing, after a uniform tax reform. For this reason we see substitution between capital and labour in the model solutions.

The figures in Table 4 show that replacing low capital income tax rates in the base year by a 26.5 percent uniform tax rate increases the user cost of capital in manufacturing sectors and some service sectors (chemicals, metals, engineering, food, other manufacturing, power, construction, distribution and transport). We see substitution of capital by labour in these sectors. Thus the effect of the reduction in capital assets is not completely compensated for by increased use of labour. Therefore output decreases in most of the manufacturing sectors, though not by as much as would have been warranted by the reduction in the use of capital in these sectors. Figures in Table 4 also show that labour is substituted by capital assets, because capital becomes less expensive, in the financial services and education sectors. Benefiting from cheaper capital services, these sectors substitute capital for labour and experience positive changes in output. For instance, two extreme cases of factor substitution are seen in the financial and chemical sectors: capital substitutes for labour substantially in the financial sector while labour substitutes for capital in the chemical sector.

d. Aggregate Welfare for Indirect Tax Reform

The basic UK model included here has four types of indirect taxes on intermediate inputs and final demand: tariffs, subsidies, duties and levies, and value added tax. Rates of indirect taxes vary across sectors (Table A5 in the appendix) and final demand categories as reported in the previous section.

The aggregate welfare impacts of replacing a non-uniform indirect tax by a uniform tax rate and lump sum taxes are reported in Table 5.

For the central case specification, the welfare gain from replacing equal yield non-uniform VAT by uniform VAT was about 0.019 percent of UK GDP. Such a welfare gain occurs because of the removal of distortions caused by differentiated VAT rates in the base year.

Equal yield replacement of all differentiated indirect tax rates by uniform tax rates across sectors leads to a gain of 0.017 percent of UK GDP. This figure is also very close to the gains from the uniform VAT case.

Finally, when we replace indirect tax rates by an equal yield lump sum tax, the welfare gain rises to 1.72 percent of UK GDP (10.8 billion), which is bigger than in all the other tax experiments reported earlier.

Table 5: *Aggregate Welfare for other cases (as % of GDP)*

Equal Yield Replacement of non-uniform VAT By Uniform Rates - Central Case Specification of Elasticities	0.0186% of UKGDP
Equal Yield Replacement of all indirect Taxes By Uniform indirect tax Rates	0.01704% of UKGDP
Equal Yield Replacement of all indirect Taxes By equal yield lump-sum tax	1.723% of UKGDP
Equal Yield Replacement of household income taxes By equal yield lump-sum tax	3.67% of UKGDP

As the last equal yield scenario shows moving completely away from the household income tax to the lump sum income taxes generates even more efficiency gain equal to 3.67 percent of the GDP (21.98 billion).

IV. Marginal Excess Burden of Taxes in the UK model

The marginal excess burden (MEB) of taxes measures the extra cost to society, in terms of money metric welfare, of each pound of revenue raised by means of a certain tax instrument. We have computed the MEB for each tax instrument included in the UK model by dividing the change in welfare (ΔW_t) by the net change in the government revenue (ΔR_t). The net change in government revenue reflects the share (g) of revenue retained by the public sector.

$$MEB_t = \frac{\Delta W_t}{g \cdot \Delta R_t} \tag{32}$$

The popular measure of the marginal excess burden of taxes, given by the area of the Harberger triangle, is related with the elasticity of demand for goods. Let P be the before tax price and $P(1+t)$ be its after tax rate t is imposed in this commodity. Change in price is ΔP, equal tax rate and it changes demand by Δq. The area of triangle under the demand curve before and after taxes represents the dead weight loss of tax changes, which is $dwl = \frac{1}{2}\Delta q \Delta p$. This area is proportional to the square of the tax rate and the elasticity of demand. The price elasticity of demand is $e = \frac{\Delta q}{\Delta p}\frac{p}{q}$. Then the relation between the change in quantity and the elasticity is $\Delta q = \frac{\Delta pq}{p}e$. Inserting this value of Δq in the equation for the dead weight loss formula we get $dwl = \frac{1}{2}\left(\frac{\Delta pq}{p}\right)e\Delta p$. The tax rate and change in prices are equal, implying $\Delta P = t$ and $dwl = \frac{1}{2}t^2\frac{eq}{p}$; normalising $p = 1$, $dwl = \frac{1}{2}t^2 eq$.

The results show that MEB figures differ according to the type of tax instrument used to raise additional revenue. Results of the UK model in terms of changes in revenue, Hicksian EVs and MEB are given in Table 6.

Table 6: *Marginal Excess Burden of Taxes (pence/£: low elasticity case)*

	Low elasticity case			High elasticity case		
Tax instrument	**MEB**	**Change in revenue**	**Hicksian money metric EV**	**MEB**	**Change in revenue**	**Hicksian money metric EV**
Capital income tax	–0.350	11305	–3962	–0.660	4449	–2936
Production tax	–0.544	6585	–3582	–0.673	876	–590
Labour income tax	–0.435	7984	–3473	–0.580	8182	–4750
Household consumption tax	–0.517	6911	–3574	–0.669	4519	–3025
Indirect tax on government consumption	–0.540	6629	–3578	–0.540	6629	–3578
Indirect tax on Investment goods	–0.542	6609	–3581	–0.614	344	–211

For the low labour supply elasticity case, the MEB ranges from 35 pence in the case of capital income taxes to 54 pence per pound of additional revenue from production taxes. If the MEB figures reflect the degree of distortion for the tax instrument used to raise the additional revenue, production taxes in intermediate goods and indirect taxes on investment goods seem to be the most distortionary tax instruments in the UK economy. The marginal excess burdens (MEB) of all other taxes are between these two figures.

These MEB figures are comparable to theoretical and empirical results on MEB available in the literature. Theoretical studies about the marginal excess burden of taxes as reported in King (1983), Browning (1987), Mayshar (1990), Atkinson (1995) state how the excess burder of taxes can rise with extra amount of distortionary taxes in an economy. On empirical side Piggott and Whalley (1985) stated that "about one quarter of the revenue raised by the UK government each year are foregone through dead weight loss". Shoven and Whalley (1984) summarising some earlier studies of tax reform studies state that "welfare loss per extra dollar of revenues raised from existing United States distortionary taxes may approach a dollar". BFSW(1985) and Fullerton and Rogers (1993) had slightly lower estimates of MEB. Our MEB estimate between 35 to 54 pence per pound of additional revenue is consistent with findings in the MEB literature.

We find MEB measures to be sensitive to the elasticities of substitution in both the consumption and production sides of the economy. As figures in Tables 7 show, MEB figures are higher for higher values of elasticities compared to corresponding numbers with lower elasticities.

V. CONCLUSION

The major findings from our study using the model are the following:

1. We show welfare gains when capital income tax rates existing in 1995 are replaced by a uniform yield preserving 26.5 percent rate across sectors and assets for low labour supply elasticity. In the central case, we find an improvement in efficiency by 0.035 percent of UK GDP (£219 million). The improvement is 0.022 percent of UK GDP (£139 million) in the case of unit elasticity specification.
2. The efficiency gain from replacing existing taxes by uniform capital income tax rates in the no equal yield capital tax reform was about 0.281 percent of UK GDP (£1.8 billion) for the low labour supply elasticity case and 0.283 for high elasticity case. The size of the government is allowed change in these cases and government consumption also is one component of aggregate welfare.
3. The computed efficiency gain from replacing capital income tax by yield preserving lump-sum taxes was 0.3 percent of UK GDP (1.9 billion).
4. We check the robustness of the welfare results by means of sensitivity analysis. The welfare impacts of moving to a yield preserving capital income tax from a set of existing taxes is positive and almost linear in the values of substitution elasticities among assets (σ_k) for a particular set of elasticities of substitution between labour and capital assets (σ_v). Similarly, it is also linear in the values of substitution elasticities between capital and labour for any particular value of substitution elasticities among capital assets. When both σ_v and σ_k are very high,

each assuming a value of 5.0, the welfare impact of switching to a uniform tax rate was about 0.11 percent of UK GDP, which amounts to nearly £691 million.

5. Changes in the relative prices of capital assets across sectors compared to the benchmark following the yield preserving capital income tax reform leads to a reallocation of capital assets across sectors. The equal yield uniform tax reform reduces the inter-sectoral and inter-asset differences in the relative user cost of capital in the counterfactual scenarios. Consequently we see a significant reallocation, up to a 20 percent increase or up to a 10 percent reduction in the use of capital assets in a low labour supply elasticity case and changes in the use of labour resources of between –5 and 5 percent across sectors, occurring in comparison to the base year. Both capital and labour reallocation effects are robust with respect to labour supply elasticity.
6. When capital inputs become relatively cheaper than labour input, producers tend to substitute capital for labour; this happens in the agriculture, finance, public administration, and education sectors. Capital becomes relatively expensive in manufacturing sectors, after a uniform tax reform. We see substitution of capital by labour in these sectors. The effect of the reduction in capital assets is however not completely compensated for by increased use of labour. Therefore output levels decrease in most of the manufacturing sectors, though not by as much as would have been warranted by the reduction in the use of capital in these sectors.
7. The marginal excess burden (MEB) of taxes is computed as a ratio of loss in welfare to a net change in government revenue. It varies according to the tax instruments in use for raising the additional pound of revenue. For the low labour supply elasticity case, the MEB ranges from 35 pence in case of capital income taxes to 54 pence per pound of additional revenue from production taxes. The effects of other taxes lie between these two numbers. If MEB figures reflect the degree of distortion for the tax instrument used to raise the additional revenue, production taxes in intermediate goods and indirect taxes on investment goods seem to be the most distortionary tax instruments in the UK economy. MEB figures are higher for higher values of labour supply elasticities compared to corresponding numbers for lower labour supply elasticities. These MEB figures are comparable to rates available in the literature (Shoven and Whalley (1984), Piggott and Whalley (1985) and BFSW(1985)).

VI. References

Atkinson A.B. (1995) Public Economics in Action: the Basic Income/Flat Tax Proposal, Oxford University Press.

Armington, P. S. (1969) "A Theory of Demand for Products Distinguished by Place of Production", International Monetary Fund *Staff Papers* 16, 159-76.

Arrow, K.J. and F.H. Hahn (1971) *General Competitive Analysis,* San Franscisco: Holden-Day.

Arrow, K.J. and G. Debreu (1954) "Existence of an Equilibrium for a Competitive Economy" *Econometrica* 22, 265-90.

Ballard, C. L., D. Fullerton, J.B. Shoven and J.Whalley (1985) *A General Equilibrium Model for Tax Policy Evaluation,* University of Chicago Press, Chicago.

Bhattarai, K. (2000) Efficiency and Factor Reallocation and Marginal Excess Burden of Taxes in the UK economy, Hull Economics Research Paper, no. 278, University of Hull.

Bhattarai, K. and J. Whalley (1999) "Role of Labor Demand Elasticities in Tax Incidence Analysis with Heterogeneous Labour Model" Empirical Economics, 24(4) 599-619.

Bhattarai, K. and J. Whalley (2000) "General Equilibrium Modelling of UK Tax Policy" forthcoming in Sean Holly and Martin Weale (eds.) *Econometric Modelling: Technique and Applications,* Cambridge University Press.

Bhattarai, K., M. Ghosh and J.Whalley (1999) "On some properties of a trade closure widely used in numerical modelling", *Economics Letters* 62 13-21.

Blundell, Duncan and Meghir (1995) Estimating Labour Supply Responses Using Tax Reforms, *Working paper* 95/7, IFS, London.

Brook, A K., D. Kendrick, A. Meeraus (1992) *GAMS: Users' Guide,* release 2.25, The Scientific Press, San Francisco, CA.

Browning, E. K. (1987) "On the Marginal Cost of Taxation", *American Economic Review,* 77(1), March, pp. 11-23.

Browning, E. K. and Johnson, W. R. (1984) "The Trade-off between Equality and Efficiency", *Journal of Political Economy,* 1984 vol. 92. no. 21 pp. 175-203.

Central Statistical Office (CSO (1995)) *Family Spending:* A report on the 1994-95 Expenditure Survey.

Debreu, G. (1954) *The Theory of Value,* Yale University Press, New Haven.

Dervis, K., J.De Melo, and S.Robinson (1985) *General Equilibrium Models for Development Policy,* CUP, New York.

Devarajan, S., J. D. Lewis, S. Robinson (1996) *A Bibliography of Computable General Equilibrium Models Applied to Developing Countries*, Harvard Institute of International Development, DDP No. 224.

Dirkse, S. P. and M. C. Ferris (1995) "CCPLIB: A collection of nonlinear mixed complementarity problems" *Optimization Methods and Software.* 5:319-345.

Financial Markets Group, LSE "How to Use P-Tax" and Manual for Turbo P-tax, *memio.*

Fullerton, D. and D.L. Rogers (1993), *Who Bears the Lifetime Tax Burden?* Brookings Institution, Washington D.C.

Giles C. and J McCrae (1983) TAXBEN: The IFS Microsimulation Tax and Benefit Model, Working paper 95/19, IFS, London, UK9 (http//www.ifs.org.uk).

Giles, C. and P. Johnson (1994) "Tax Reform in the UK and Changes in the Progressivity of the Tax System, 1985-95", *Fiscal Studies,* vol. 15, no. 3, pp. 64-86.

Goulder, L.H., J. Shoven and J. Whalley (1983) "Domestic Tax Policy and Foreign Sector: The Importance of Alternative Foreign Sector Formulations to Results from a General Equilibrium Tax Analysis Model" in M. Feldstein ed. *Behavioral Simulation Methods in Tax Policy Analysis,* Chicago University Press.

Goulder, L.H., and L.H.Summers (1989) "Tax Policy, Asset Prices and Growth: A General Equilibrium Analysis", *Journal of Public Economics,* 38: 265-296, North Holland.

Harberger, A. C. (1962), "The incidence of the corporation income tax" *Journal of Political Economy* 70 (June):215-40.

Institute of Fiscal Studies (2002) Green Budget, IFS, London.

Inland Revenue (1991) "How to Use P-Tax", *memio,* Economics Unit, London.

King M.A. (1983) Welfare Analysis of Tax Reform using Household Data, *Journal of Public Economics,* 21 183.214.

King, M.A. and D. Fullerton (1984) *The taxation of income from capital: a comparative study of the United States, the United Kingdom, Sweden and West Germany,* Chicago University Press.

King, M.A. and M.H. Robson (1988) "Manual for Turbo P-tax", *LSE,* London.

Mayshar J. (1990) On Measures of Excess Burden and Their Application, *Journal of Public Economics,* 43, pp. 263-289.

Mercenier, J. and Srinivasan, T.N. ed. (1994) *Applied General Equilibrium and Economic Development: Present Achievement and Future Trends,* University of Michigan Press, Ann Arbor.

Office of National Statistics (ONS (1995)) *Input Output: Tables for the United Kingdom,* HMSO, London.

Piggott, J. and J.Whalley (1985) *UK Tax Policy and Applied General Equilibrium Analysis,* Cambridge University Press.

Rutherford, T. F. (1995) "Extension of GAMS for Complementary Problems Arising in applied Economic Analysis" *Journal of Economic Dynamics and Control* 19 1299-1324.

Rutherford, T. F. (1997) *The GAMS/ MPSGE and GAMS/MILES user notes,* GAMS Development Corporation, Washington D.C.

Scarf, H. E. (1986) The Computation of Equilibrium Prices, in Scarf H. E and Shoven John B. ed. *Applied General Equilibrium Analysis,* Cambridge University Press.

Siddorn, G. (1999) Derivation of 1995 Symmetric Use Matrices, mimeo, *Economics Unit*, Inland Revenue, F4 West Wing, Somerset House, Strand, London WC2R 1LB *eview Income and Wealth,* 29, 175-204.

Shoven, J.B. and J.Whalley (1992) *Applying General Equilibrium,* Cambridge University Press, 1992.

Shoven, J. B. and J.Whalley (1973)"General Equilibrium with Taxes: A Computation Procedure and an Existence Proof" *Review of Economic Studies* 40, 475-90.

Shoven, J.B. and J.Whalley (1977) "Equal Yield Tax Alternatives: General Equilibrium Computational Techniques." *Journal of Public Economics* 8, 211-24.

Shoven, J.B. and J.Whalley (1984) "Applied General-Equilibrium Models of Taxation and International Trade: An Introduction and Survey", *Jorunal of Economic Literature,* vol. XXII, Sept,pp.1007-1051.

Taylor, L. ed. (1990) *Socially Relevant Policy Analysis: Structuralist Computable General Equilibrium Models for the Developing World,* MIT Press, Cambridge 1990.

Walras, L. (1954) Elements of Pure Economics, Allen and Unwin, London.

Whalley, J. (1985) *Trade Liberalization Among Major World Trading Areas,* MIT Press, Cambridge.

Table A1: *Aggregation of 123 sectors into 16 sectors from 1990 Input-Output Sectoral Classification*

INDUSTRY/ ASSET	1990 I-O Sectors	1990 sectoral code	1995 sectoral code
Agriculture	Agriculture, Forestry, Fishing	1,2,3	1-3
Extraction	Extraction – oil and gas	5	5
Other mining & quarrying	Coal extraction, stone, clay, sand, gravel, metal ores and minerals	4,14, 10	4,6,7
Chemicals	Coke ovens, oil proc, nuclear fuel, inorganic chemicals, organic chemicals, fertilisers, synthetic resins, paints, dyes, printing ink, special chemical for industry, pharmaceutical products, soap and toilet preparations, chemical products, man-made fibres	6, 20-29	35-46
Metals and mineral products	Iron and Steel, Aluminium, other non-ferrous metals, structural clay products, Cement, lime and plaster, concrete, asbestos, abrasive prods, glass, refractory and ceramic goods, metal casting, metal doors, windows, packaging products of metals, industrial plant and steel work, engineers small tools	11-13, 15-19, 30-34, 37	49-61
Engineering	Agricultural machinery and tractors, metal working machine tools, textile etc machinery, process machinery and contractors, mining equipment, mech power transmission equipment, other machinery, ordnance samll arms and ammunition, insulated wires and cables, basic electrical equipment, industrial electrical equipment, telecommunications etc. equipment, electronic components, electronic consumer goods, demestic electric appliances, electric lighting equipment, instrument engineering	35,36,38-52,57	62-76
Food, drinks and tobacco	Oils and fats, slaughtering and meat processing, milk and products, fruit vegetable and fish processing, grain milling and starch, bread, biscuits, sugar, confectionary, animal feeding stuffs, miscellaneous foods, alcoholic drink soft drinks, tobacco	58-70	8-20
Other manufacturing	Motor vehicles and parts, shipbuilding and repairing, aerospace etc, other vehicles, woollen and worsted, cotton spinning and weaving, hosiery and other knitted goods, textile finishing, carpets, jute, leather and leather goods, footwear, clothing furs, household and other textiles, timber and wood products, wooden furniture, pulp, paper and board, paper and board products, printing and publishing, rubber products, processing of plastics, jewellery and coins, sports goods and toys, other goods	53-56, 71-90	21-34, 47-48,77-84

Electricity, gas and water	Electricity production, gas, water supply	7,8,9	85-87
Construction	Construction	91	88
Distribution, hotels, etc.	Wholesale distribution, retail distribution, distribution and vehicles repairs, hotels catering, pubs etc.	92,93,94,95	89-92
Transport, storage, and communication	Railways, road and other inland transport, sea transport, air transport, transport services, postal services, telecoomunication	96-102	93-99
Financial sector	Banking and finance, insurance, auxiliary financial services, estate agents, legal services, accountancy services, other professional services, advertising, computing services, other business services, renting of movables, owning and dealing in real estate, research and development	103-114, 118	100-103, 105-114
Public administration	Public administration	115	115
Education, health and social work	Sanitary services, education, health services, recreation and welfare services, personal services, domestic services	116, 117,119-122	116-123
Housing services	Ownership of dwelling	123	104

Source: *General equilibrium model of the UK economy.*

Table A2: *A 16 Sector Industry by Industry Input-Output Table of the United Kingdom 1995*

I x I Domestic Use Matrix	Agriculture	Extraction	Other Mining	Chemicals	Metals	Engineering	Food, drink	Other Manuf.	Utilities	Construction	Distribution	Transport	Financial	Public Admin	Educ. Health,	Housing	Total interme-diate	Consumers' expenditure	GGFC	GDFCF	Stocks	Exports	Total final demand	Total
Agriculture	2,096	0	14	27	7	5	12,132	435	0	4	564	48	15	0	148	0	**15,495**	6,730	42	0	0	1,942	8,713	**24,208**
Extraction	0	2,439	0	4,697	3	0	0	0	3,622	0	0	0	0	0	0	0	**10,762**	0	0	0	0	6,942	6,942	**17,704**
Other Mining	20	0	353	218	846	26	45	130	1,897	401	105	17	8	0	57	0	**4,124**	339	47	0	0	983	1,369	**5,493**
Chemicals	1,433	10	37	3,899	433	546	571	1,484	466	737	1,299	1,254	913	0	3,204	19	**16,304**	3,764	3,116	0	261	28,663	35,804	**52,108**
Metals	110	162	192	1,225	7,249	6,320	1,831	5,197	50	7,074	503	389	5	0	84	0	**30,392**	346	588	7,158	779	10,230	19,101	**49,493**
Engineering	0	576	317	682	1,254	5,705	528	2,432	634	788	848	1,808	1,018	0	1,567	36	**18,192**	0	1,589	2,613	332	50,923	55,457	**73,649**
Food, drink	2,797	52	25	356	82	120	6,382	350	64	51	6,589	650	1,058	0	1,796	4	**20,377**	25,904	411	0	153	10,270	36,737	**57,114**
Other Manuf.	583	80	134	1,781	1,839	3,005	2,816	16,404	474	4,242	6,702	4,139	8,242	0	3,340	283	**54,064**	18,082	3,872	8,933	1,185	39,858	71,928	**125,992**
Utilities	279	0	160	1,330	1,596	1,189	931	1,980	12,273	272	1,201	857	1,184	0	705	23	**23,981**	16,353	1,323	0	0	62	17,738	**41,719**
Construction	172	0	122	109	32	56	0	31	0	21,085	603	151	1,985	0	146	3,929	**28,420**	3,521	4,414	47,764	285	0	55,983	**84,404**
Distribution	1,005	200	206	1,479	2,489	4,115	1,647	3,724	355	1,371	4,164	2,470	2,276	0	790	0	**26,289**	111,181	1,229	2,586	0	13,701	128,698	**154,987**
Transport	245	704	335	1,232	2,047	1,415	1,583	3,614	183	887	14,871	15,642	17,082	0	3,175	198	**63,216**	19,715	2,637	779	0	12,194	35,324	**98,540**
Financial	1,949	671	471	4,070	2,781	6,194	4,205	9,177	1,884	10,483	22,425	12,387	50,836	0	13,435	15,221	**156,189**	25,373	8,458	8,483	0	12,545	54,859	**211,047**
Public Admin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	0	63,843	0	0	0	63,843	**63,843**
Educ. Health,	378	1	41	520	253	581	496	2,618	179	242	1,001	1,369	4,031	0	7,756	67	**19,535**	43,653	46,265	0	0	4,504	94,422	**113,957**
Housing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	53,269	0	0	0	0	53,269	**53,269**
Total intermediate	11,067	4,895	2,410	21,626	20,912	29,276	33,168	47,576	22,081	47,638	60,876	41,182	88,652	0	36,201	19,781	**487,339**	328,229	137,832	78,316	2,995	192,816	740,188	**1,227,527**
Imports	1,630	989	425	10,639	7,613	15,965	8,827	30,336	3,612	5,151	3,532	4,895	3,949	0	2,960	19	**100,541**	52,021	9,995	28,174	1,563	2,494	94,248	**194,789**
Duty on imports	34	6	5	136	101	214	171	405	48	66	51	26	2	0	9	0	**1,273**	547	91	382	20	32	1,073	**2,346**

VAT	0	0	0	0	0	0	0	0	0	0	0	218	3,259	0	1,181	0	**4,658**	33,257	3,915	3,731	0	0	40,902	**45,561**
Duties and levies	211	2	103	1,175	344	176	460	331	1,378	130	1,275	2,026	896	0	344	36	**8,887**	22,713	434	0	0	0	23,147	**32,034**
Other taxes and subsidies	-265	-25	-10	-50	-53	-46	-1,454	-212	-10	-34	-443	-404	-409	0	-186	-6	**-3,607**	4,559	-577	-45	4	-556	3,384	**-223**
Value added – Labour	7,143	1,409	1,822	10,151	15,790	18,529	9,691	36,483	5,492	29,947	61,877	35,191	70,149	60,316	69,067	0	**433,059**	0	0	0	0	0	0	**433,059**
Value added – Gross profits etc	4,388	10,428	738	8,432	4,786	9,536	6,250	11,074	9,118	1,505	27,820	15,406	44,549	3,527	4,381	33,440	**195,376**	0	0	0	0	0	0	**195,376**
Total inputs	**24,208**	**17,704**	**5,493**	**52,108**	**49,493**	**73,649**	**57,114**	**125,992**	**41,719**	**84,404**	**154,987**	**98,540**	**211,047**	**63,843**	**113,957**	**53,269**	**1,227,526**	**441,325**	**151,691**	**110,558**	**4,582**	**194,786**	**902,942**	**2,130,468**

Source: *ONS, Input-Output Tables of the United Kingdom, 1995; Siddorn (199).*

Table A3: *Industry by Industry Import Use Matrix for the UK economy 1995*

I x I Imports Use Matrix	Agriculture	Extraction	Other Mining	Chemicals	Metals	Engineering	Food, drink	Other Manuf.	Utilities	Construction	Distribution	Transport	Financial	Public Admin	Educ. Health,	Housing	Total intermediate	Consumers' expenditure	GGFC	GDFCF	Stocks	Exports	Total final demand	Total
Agriculture	462	0	0	2	0	0	2,342	394	0	0	546	9	0	0	0	0	**3,755**	1,471	0	0	0	46	1,517	**5,272**
Extraction	0	133	0	1,532	0	0	0	0	1,613	0	0	0	0	0	0	0	**3,278**	0	0	0	0	0	0	**3,278**
Other Mining	0	0	68	359	540	31	4	50	312	540	0	0	0	0	0	0	**1,905**	29	3	0	0	2,003	2,035	**3,941**
Chemicals	802	11	142	7,931	1,028	1,274	844	7,476	382	196	165	609	22	0	299	0	**21,182**	2,259	873	0	199	165	3,495	**24,677**
Metals	26	180	57	222	5,249	2,251	378	1,745	0	1,690	64	0	0	0	0	0	**11,863**	0	0	3	220	0	222	**12,085**
Engineering	45	161	61	13	286	11,980	22	2,177	855	770	46	791	78	0	119	0	**17,403**	6,220	3,123	22,859	148	164	32,513	**49,916**
Food, drink	291	0	0	275	0	0	4,641	36	0	0	936	53	0	0	0	0	**6,232**	8,812	348	0	18	19	9,198	**15,430**
Other Manuf.	0	0	79	300	478	369	565	18,399	12	1,900	1,206	641	60	0	357	0	**24,365**	24,075	2,893	5,312	979	98	33,357	**57,722**
Utilities	0	0	0	3	4	1	2	3	432	0	0	0	0	0	0	0	**446**	0	0	0	0	0	0	**446**
Construction	0	0	0	0	0	0	0	0	0	44	0	0	0	0	0	0	**44**	0	0	0	0	0	0	**44**
Distribution	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	3,518	0	0	0	0	3,518	**3,518**
Transport	0	504	11	0	5	0	4	0	0	2	530	2,720	375	0	60	0	**4,211**	4,036	342	0	0	0	4,378	**8,590**
Financial	4	1	8	0	20	50	22	0	4	10	35	33	3,369	0	886	19	**4,463**	0	1,328	0	0	0	1,328	**5,791**
Public Admin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	0	416	0	0	0	416	**416**
Educ. Health,	0	0	0	1	3	8	2	55	2	0	3	38	45	0	1,238	0	**1,395**	1,035	669	0	0	0	1,704	**3,099**
Housing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	566	0	0	0	0	566	**566**
Total Imports	**1,630**	**989**	**425**	**10,639**	**7,613**	**15,965**	**8,827**	**30,336**	**3,612**	**5,151**	**3,532**	**4,895**	**3,949**	**0**	**2,960**	**19**	**100,541**	**52,021**	**9,995**	**28,174**	**1,563**	**2,494**	**94,248**	**194,789**

Source: *ONS, Input-Output Tables of the United Kingdom, 1995; Siddorn (199).*

Table A4: *Effective Tax rates on capital income by assets for year 1995 used in the UK tax model*

INDUSTRY/ASSET	Buildings	P&M long life	P&M short life	Vehicles	Dwellings	P&M long life (new life '95)
Agriculture	46.2	14.6	25.3	16.9	0.0	25.3
Extraction	51.1	15.9	27.8	21.3	0.0	27.8
Other mining & quarrying	44.3	14.6	23.3	21.3	0.0	23.3
Chemicals	39.9	13.0	17.9	21.3	0.0	17.9
Metals and mineral products	39.7	12.0	17.1	21.3	0.0	17.1
Engineering	39.7	12.0	18.3	21.3	0.0	18.3
Food, drinks and tobacco	39.7	12.4	17.8	21.3	0.0	17.8
Other manufacturing	39.7	12.9	19.1	22.7	0.0	19.1
Electricity, gas and water	40.8	13.6	30.0	21.3	0.0	30.0
Construction	39.7	14.6	23.5	21.3	0.0	23.5
Distribution, hotels, etc.	39.7	13.3	23.9	21.3	0.0	23.9
Transport, storage, and communication	39.7	16.4	26.5	18.5	0.0	26.5
Financial sector	50.7	13.3	24.7	21.3	0.0	24.7
Public administration	50.7	13.3	23.8	21.3	0.0	23.8
Education, health and social work	51.3	13.3	22.2	21.3	0.0	22.2
Housing services	0.0	0.0	0.0	0.0	0.0	0.0

Source: *P-Tax calculator, Inland Revenue 1998.*

Table A5: *Composite indirect tax rates on final demand expressed as percent of net prices for year 1995*

	Tax on household consumption		**Tax on investment**		**Tax in government consumption**	
	Domestic sales	**Imports**	**Domestic sales**	**Imports**	**Domestic sales**	**imports**
Agric	-10.9	4.9			-7.1	2.6
Minin	5.4	5.4			16.0	16.0
Chemi	163.1	167.2		1.5	14.7	16.3
Metal	17.3	17.3	3.3	4.7	17.5	17.5
Engin	15.4	16.9	5.0	6.6	16.6	18.2
Foodd	47.5	49.0			2.0	3.1
Othma	14.6	16.0	5.4	6.8	10.8	12.3
Power	9.0	9.0			16.9	16.9
Const	13.9	14.0	2.4	2.5	17.0	17.1
Distr	12.8	12.8			7.9	7.9
Trans	5.9	8.7	-2.2	0.3	6.7	9.3
Finan	1.1	1.1	0.3	0.3	6.1	6.1
Educa	6.3	7.5			-0.8	0.3
House	-2.0					

Source: *GE data set, Inland Revenue 1998.*