

A Dynamic Multi-Sectoral General Equilibrium Tax Model of the UK Economy

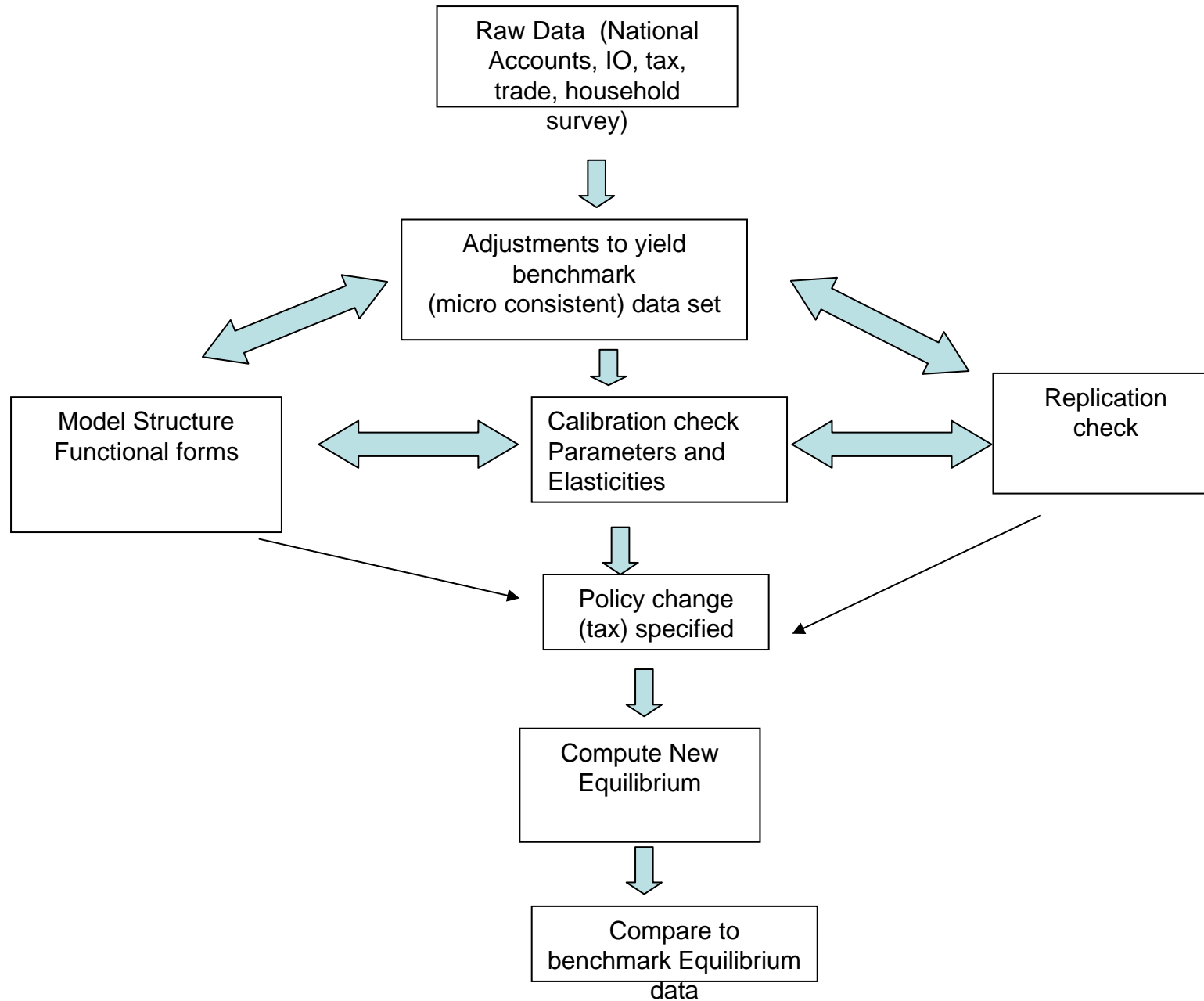
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Research Questions

- What are the dynamic efficiency effects of tax reform ?
- How do unanticipated tax changes affect sectoral output, employment and capital formation in the economy?
- How do anticipated tax changes affect sectoral output, employment and capital formation?
- Does the international openness of capital markets alter the dynamic effects of tax changes?
- How to compute a dynamic general equilibrium model for a decentralised economy?



Steps for Implementation of a General Equilibrium Model

Structure of the Model

- Institutions

Infinitely lived households

Profit maximising producers

Government

Traders

- Time Horizon 65 years

Markets

16 commodities
(domestically produced
and imports)

Labour

Sector Specific Capital

- Use the model

Analysis of growth paths
(output, employment,
investment and capital
stock)

Dynamic efficiency analysis

Capital accumulation

Saving-investment-
retirement decision

Intertemporal redistribution

Literature

Debreau (1954), Solow (1956),
Cass(196), King and Fullerton (1984),
Aurback and Kotlikoff (1987), Ballard,
Fullerton, Shoven and Whalley (1985),
Piggott and Whalley (1985), Bhattarai and
Whalley (1999), Hutton and Kenc (1994),
Perroni (1995), Rutherford (1995),
Bhattarai (1997,1999)

Preferences and Demand for Goods and Services

$$\sum_{t=0}^{\infty} \beta^t \frac{U_t^{1-\sigma} - 1}{1-\sigma}$$

$$U(C_t, L_t) = \left(\alpha_c C_t^{\frac{\gamma-1}{\gamma}} + (1-\alpha_c) L_t^{\frac{\gamma-1}{\gamma}} \right)^{\frac{\gamma}{\gamma-1}}$$

$$U = \sum_{t=0}^{\infty} \left(\frac{1}{1+\rho} \right)^t \frac{\left(\alpha_c C_t^{\frac{\gamma-1}{\gamma}} + (1-\alpha_c) L_t^{\frac{\gamma-1}{\gamma}} \right)^{\frac{\gamma}{\gamma-1} (1-\sigma) - 1}}{1-\sigma}$$

Life Time Budget Constraint

$$R_t^{-1} = \prod_{s=0}^{t-1} 1/(1+r_s) \quad P_t = \mathcal{G} \prod_{i=1}^n p_{i,t}^{\alpha_i}$$

$$W = \frac{J_0}{1+r_0^c} + \frac{J_1}{(1+r_0^c)(1+r_1^c)} + \dots + \frac{J_2}{\prod_s^t (1+r_s^c)} + \dots = \sum_{t=0}^{\infty} R_t^{-1} J_t$$

$$J_t = (1-t_l)w_t L S_t + (1-t_k)r_t K_t + TR_t$$

$$S_t = J_t - P_t C_t$$

$$\sum_{t=0}^{\infty} R_t^{-1} (P_t C_t + w_t L_t) = W$$

Production and Supply

$$\Pi_{j,t}^y = \left[\left((1 - \delta_i^e) PD_{i,t} \frac{\sigma_y - 1}{\bar{\sigma}_y} + \delta_i^e PE_{i,t} \frac{\sigma_y - 1}{\bar{\sigma}_y} \right) \right]^{\frac{1}{\sigma_y - 1}} \\ - \theta_j^v PY_{j,t}^v - \theta_j^d \sum_i a_{i,j}^d P_{i,t} - \theta_j^m \sum_i a_{i,j}^m PM_{j,t}$$

$$Y_{i,t} = \Omega_i \left((1 - \delta_i) (K_{i,t})^{\gamma_i} + \delta_i (LS_{i,t})^{\gamma_i} \right)^{\frac{1}{\gamma_i}}$$

$$PY_{i,t} Y_{i,t} = w_t LS_{i,t} + r_t K_{i,t}$$

$$GY_{i,t} = \min \left(Y_{i,t}, \left(\frac{DI_{i,j,t}}{a_{i,j}^d} \right)_{i=j}, \left(\frac{MI_{i,j,t}}{a_{i,j}^m} \right)_{i=j} \right)$$

Capital Accumulation

$$K_{i,t+1} = K_{i,t}(1 - \delta_i) + I_{i,t}$$

$$I_{i,T} = K_{i,T}(g + \delta_i)$$

$$LS_t = \bar{L}_t - L_t$$

Arbitrage Condition for Investment

$$R_{i,t} - \delta_i \leq r_t$$

$$I_{i,t} \geq 0$$

$$I_{i,t}(R_{i,t} - \delta_i - r_t) = 0$$

Trade and Absorption

$$A_{i,t} = \Phi \left(\delta_i^d D_{i,t} \frac{\sigma_m - 1}{\sigma_m} + \delta_i^m M_{i,t} \frac{\sigma_m - 1}{\sigma_m} \right) \frac{\sigma_m}{\sigma_m - 1}$$

$$PA_{i,t} A_{i,t} = PD_{i,t} D_{i,t} + PM_{i,t} M_{i,t}$$

$$A_{i,t} = CC_{i,t} + G_{i,t} + I_{i,t} + \sum_j DI_{i,j,t} + \sum_j MI_{i,j,t}$$

$$GY_{i,t} = \Theta \left((1 - \delta_i^e) D_{i,t} \frac{\sigma_y - 1}{\sigma_y} + \delta_i^e E_{i,t} \frac{\sigma_y - 1}{\sigma_y} \right) \frac{\sigma_y}{\sigma_y - 1}$$

$$PA_{i,t} A_{i,t} = PD_{i,t} D_{i,t} + PM_{i,t} M_{i,t}$$

$$A_{i,t} = CC_{i,t} + G_{i,t} + I_{i,t} + \sum_j DI_{i,j,t} + \sum_j MI_{i,j,t}$$

$$GY_{i,t} = \Theta \left((1 - \delta_i^e) D_{i,t} \frac{\sigma_y - 1}{\sigma_y} + \delta_i^e E_{i,t} \frac{\sigma_y - 1}{\sigma_y} \right) \frac{\sigma_y}{\sigma_y - 1}$$

$$P_{i,t} GY_{i,t} = PD_{i,t} D_{i,t} + PE_{i,t} E_{i,t} \quad \Pi_{j,t}^y \leq 0$$

$$\sum_i PE_{i,t} E_{i,t} = \sum_i PM_{i,t} M_{i,t}$$

$$\sum_t (1 + r^W)^{-t} \sum_i PE_{i,t} E_{i,t} = \sum_t (1 + r^W)^{-t} \sum_i PM_{i,t} M_{i,t}$$

Tax Revenue and Public Spending

$$\begin{aligned} REV_t = & \sum_i t_i^k r_t K_{i,t} + \sum_i t_i^{vc} P_{i,t} CC_{i,t} \\ & + \sum_i t_i^{vg} P_{i,t} G_{i,t} + \sum_i t_i^{vk} P_{i,t} I_{i,t} + \sum_i t_l^w LS_t \\ & + \sum_i t_i^m PM_{i,t} M_{i,t} + \sum_i t_i^p P_{i,t} GY_{i,t} \end{aligned}$$

$$REV_t = G_t + TR_t$$

$$G = \sum_i PA_i GD_i + \sum_i PA_i GM_i$$

Competitive Equilibrium Prices and Quantities such that

1. households maximise intertemporal utility subject to their wealth constraint;
2. investors maximise intertemporal profits subject to arbitrage conditions in capital markets;
3. producers minimise costs subject to technology constraints;
4. unit profits are zero in all production sectors;
5. markets for goods and services clear;
6. the government account constraint is satisfied;
7. the balance of payments condition is fulfilled
8. the economy grows at a constant rate beyond a certain terminal period T .

Calibration of the Dynamic Economy

$$U = \sum_{t=1}^T \beta^t U(C_t) + \sum_{t=T+1}^{\infty} \beta^t U(C_t)$$

$$I_T = K_T(g + \delta) \qquad P_t = P_{t+1}^k$$

$$P_t^k = (1+r)P_t \qquad P_t^k = r_1^k + (1-\delta)P_{t+1}^k$$

$$r_t^k = (r + \delta)P_t^k \qquad \frac{P_{t+1}^k}{P_t^k} = \frac{1}{1+r}$$

$$\bar{V}_i = r_t^k K_i$$

$$\bar{V}_i = (r + \delta_i)K_i$$

$$I_i = \frac{(g + \delta_i)}{(r + \delta_i)} \bar{V}_i$$

$$K_i = \frac{\bar{V}_i}{(r + \delta_i)}$$

Table 1
Basic Parameters of the UK Model

Steady state growth rate for sectors (g)	0.02
Net interest rate in non-distorted economy (r)	0.05
Reference quantity for each sector, Q_{rf}	$(1+g)^{t-1}$
Reference price for each sector, P_{rf}	$1/(1+r)^{t-1}$
Elasticity of transformation between UK's Domestic supplies and exports to the Rest of the World (ROW), σ_y	1.5
Elasticity of substitution between UK's domestic products and imports from rest of the World (ROW), σ_m	1.5
Intertemporal elasticity of substitution, σ	0.5
Intra temporal elasticity of substitution between leisure and composite goods, γ	0.5
Elasticity of substitution in consumption goods Across sectors, σ_c	0.5

Table 3
Counterfactual tax rates in the dynamic UK model

Tax experiment	Counterfactual tax rates
Capital income tax rate	25.0
Indirect tax on private consumption	10.0
Indirect tax on public consumption	5.0
Indirect tax on investment	5.0
Production tax rates	5.0
Tariff rates	1.0
Household income tax rate	15.0

Table 2
Depreciation, Capital Income and Indirect Tax Rates (%)

Industry	Elasticity of substitution between labour and capital (γ_i)	Depreciation rate (annual %)	Capital income tax rate	Indirect tax on private consumption	Indirect tax on public consumption	Indirect tax on investment	Product on tax rates	Tariff rates
Agric	1.2	8.3	41.4	1.6	7.7		-10.9	2.5
Extra	1.7	16.6	26.2					2.5
Minin	1.5	10.4	31.0	12.5	32.7		-0.6	2.5
Chemi	1.7	5.6	24.0	15.4	8.3		14.3	2.5
Metal	1.6	5.4	25.3	100.8	47.5	3.8	0.0	2.5
Engin	1.5	6.0	27.6		31.1	4.9	0.0	2.5
Food	1.0	5.4	28.0	17.0	3.5		12.2	2.5
Othma	0.9	6.4	26.2	26.3	19.	6.1	0.0	2.5
Power	1.5	4.1	28.9	5.7	22.1		3.4	2.5
Constr	1.0	9.4	30.3	13.3	27.8	2.5	-0.1	
Distr	1.6	5.9	33.9	4.4			5.4	
Trans	1.6	7.5	29.7	8.3	15.3	0.1	-2.2	2.5
Finan	1.6	6.9	41.9	1.0	11.0	0.3	2.0	2.5
PubAD	1.6	4.	45.8					2.5
EducA	1.6	3.8	48.1	7.5	0.6		1.9	2.5
House	1.0	2.0					-0.3	2.5

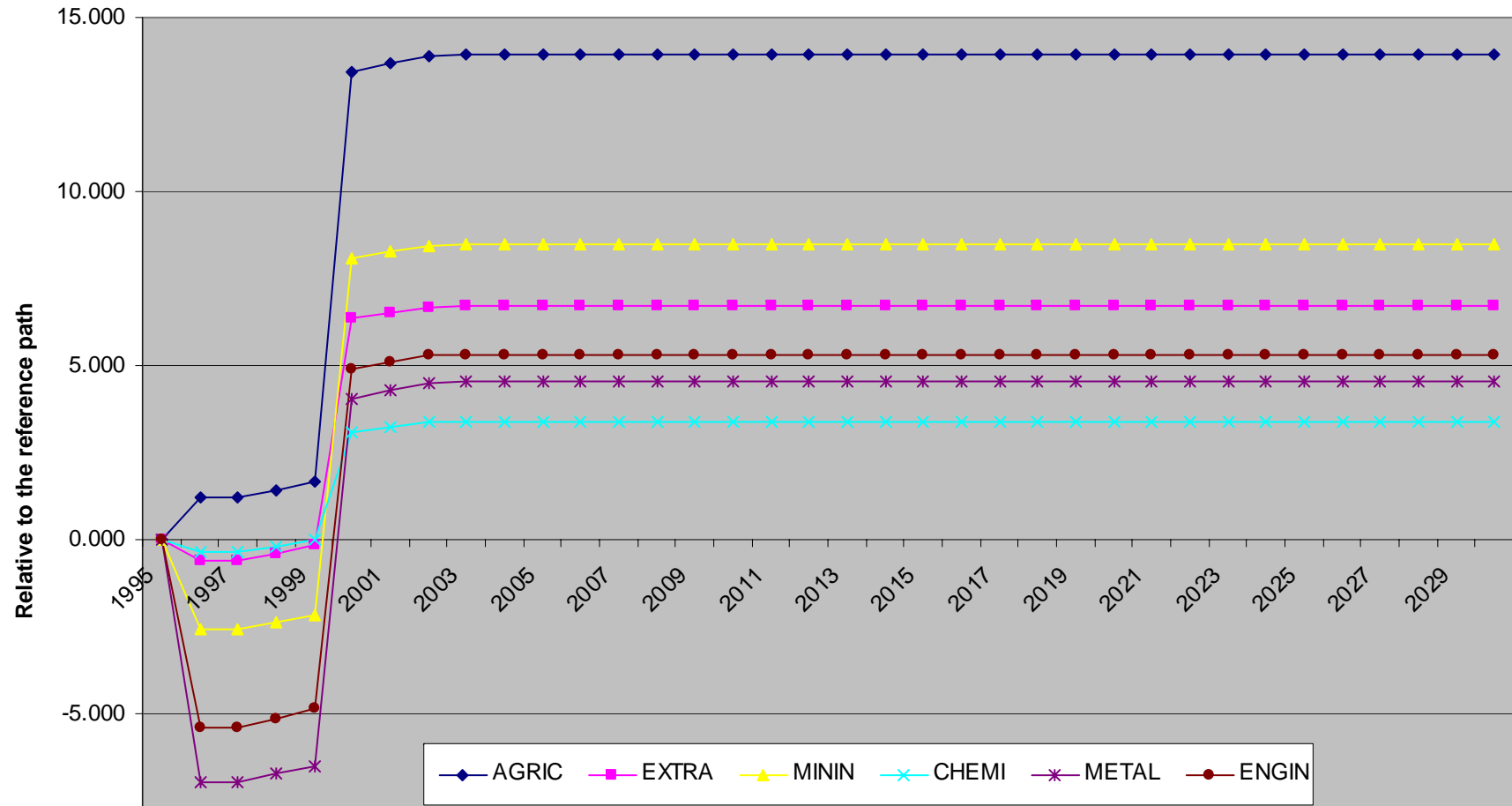
Table 4
Efficiency effects of tax reform in the dynamic UK
model

Efficiency change as a percentage of base GDP (%)

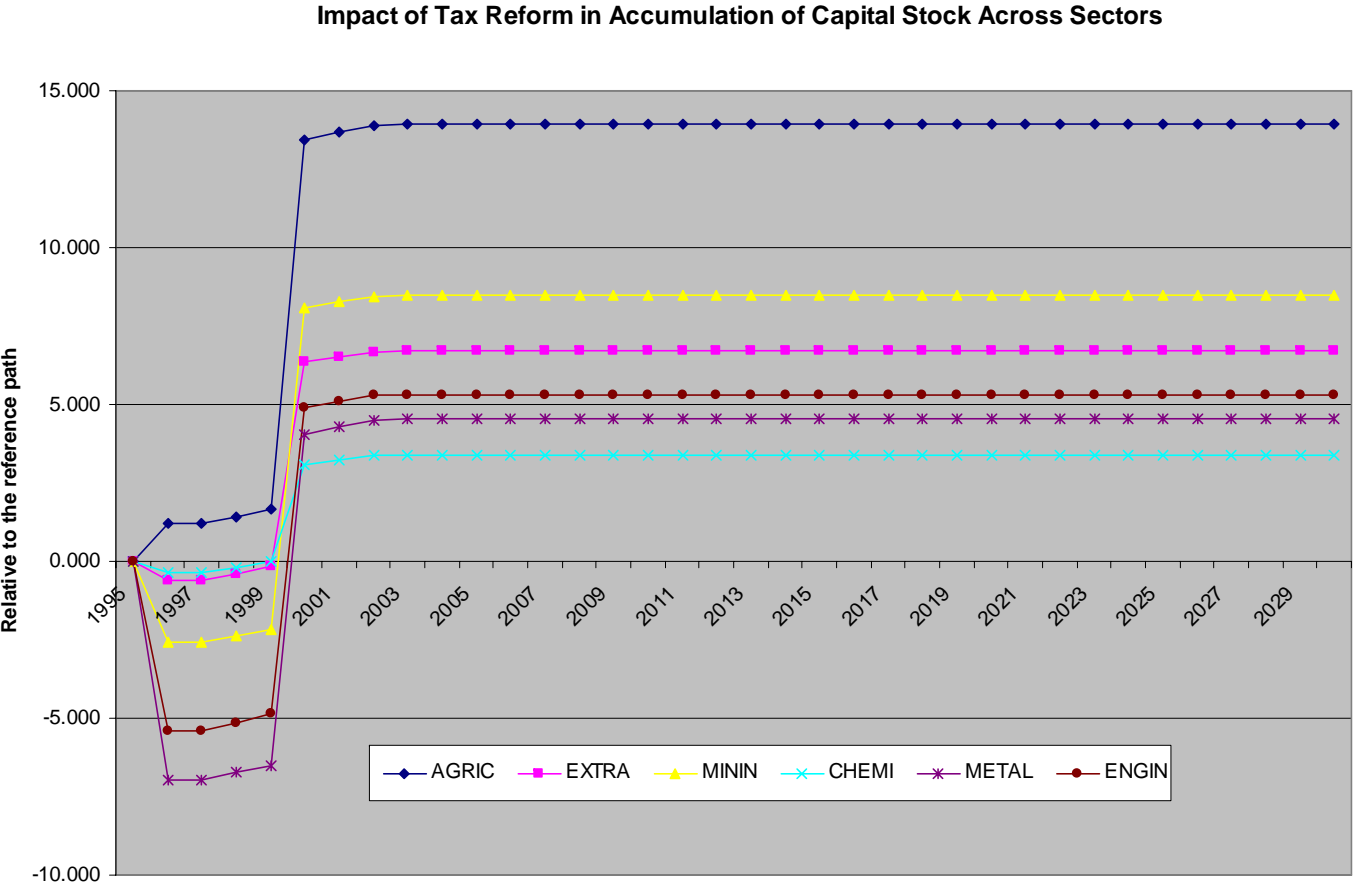
	Closed capital market with no announcement	Closed capital market with announcement	Open capital market with no announcement
Capital income tax	0.699	0.633	0.768
Labour income tax	-2.054	-2.054	-2.195
Production tax	1.421	1.284	1.442
Investment tax	-0.085	-0.048	-0.106
Household consumption tax	0.112	0.557	0.693
Government consumption tax	0.297	0.256	0.317
Tariffs	0.070	0.053	0.081

$$UW = 100(LU - 1) \frac{C_0}{GDP_0}$$

Impact of Tax Reform in Accumulation of Capital Stock Across Sectors



Impact of Tax Reform on Capital Accumulation



Data set

Appendix A

A brief note on the data set

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

COUNTRY/ASSET	1990 I-O Sectors	1990 sectoral code	1995 sectoral code
	Agriculture, Forestry, Fishing	1,2,3	1-3
	Extraction – oil and gas	5	5
& quarrying	Coal extraction, stone, clay, sand, gravel, metal ores and minerals	4,14, 10	4,6,7
	Coke ovens, oil production, 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
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
	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, domestic electric appliances, electric lighting equipment, instrument engineering	35,36,38-52,57	62-76
and tobacco	Oils and fats, slaughtering and meat processing, milk and products, fruit vegetable and fish processing, grain milling and starch, bread, biscuits, sugar, confectionery, animal feeding stuffs, miscellaneous foods, alcoholic drink soft drinks, tobacco	58-70	8-20
acturing	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

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

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 intermediate	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	1,227,52
Exports	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
NET	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
Taxes 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	2,130,46

Source: ONS, Input-Output Tables of the United Kingdom, 1995; Siddon (1999).

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

Final 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 (1999).

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Real GDP Of YK (Million Pounds)

