General Equilibrium Impacts Of Energy and Pollution Taxes in UK

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Abstract

This paper investigates how the capital accumulation across sectors generates higher rates of economic growth across sectors but also raises the level of pollution analysing the results from the multisectoral and multi household dynamic general equilibrium models of energy and environment taxes for the UK economy (GEMEETUK). Growth and redistribution are analysed simultaneously including the optimal labour leisure choices of households who are under their budget constraints and subject to lower level of lifetime utility because of environmental taxes. The pollution taxes on the use of capital and labour inputs in production across sectors link the energy, environment and growth of economy where air, water, land pollution is essentially a by-product of processes of production. How the evolution of economy differs with and without energy and pollution taxes are shown using dynamic series of model results on output, employment, investment and capital stocks by sectors and households at micro level and corresponding aggregates at the macroeconomic level with a conclusion that the mechanism of pollution control should rely on energy saving or energy efficiency measures than on the energy and environmental taxes to let economy move in the balanced growth path.

Key words: Growth, redistribution, energy, pollution, UK economy

JEL Classification: C68, D63, O15

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1 Introduction

How the man made factors of production, buildings and structures, machines and equipment, networks of transport and communication, skill and expertise including those contained in the specialised software enhance the productivity of workers is well investigated in the literature (Maddison (1991), Ramsey (1928), Hicks (1937), Harrod (1939), Domar (1947), Solow (1956), Kaldor (1961), Uzawa (1962) Cass (1965), Koopmans (1965), Lucas (1988), Romer (1989), Parente (1994), Perroni (1995), Sargent and Ljungqvist (2005)). How they fit in the multisectoral dynamic real economy benchmarked to the detailed micro-consistent data contained in the input output table of an economy is of more recent development (Auerbach and Kotlikoff (1987), Rutherford (1995) , Kehoe, SriNivashan and Whalley (2005)). Earlier multisectoral models such as Leontief (1949), Harberger (1962), Jorgensen (1961) Ballard-Fullerton-Shoven-Whalley (BFSW(1985)), and Robinson (1991), Fullerton and Rogers (1993), Mercenier and Srinivasan (1994) and Dixon et al. (1992) had mainly relied in the comparative static framework. Bohringer and Rutherford (2004) Grubb (2004) Green and Newbery (1992), Manne and Richel (1992), McFarland, Reilly and Herzog (2002) Nordhaus (1979), Perroni and Rutherford (1993), Backus and Crucini (2000), Boyd and Doroodian (2001), Coupal and Holland (2002), Grepperud and Rasmussen (2004), Jansen and Klaassen (2000), Kumbaroglu (2003), Spear(2003) and Thompson (2000) use partial or general equilibrium models with the electricity sector to examine how pollution arises in process of generating energy required for efficient functioning of economies under investigation. How is the production over time generates pollution at the national or the global level? How does it affect the climate change? What are its consequences? Who hears the burden of adjustment? How is the dividend from the improved environment from emission control at the global level shared by advanced or developing economies under the Montreal or Kyoto protocols? These questions are examined in several studies including those of Aronsson, (1999), Bohringer and Conrad and Loschel (2003), Crettez and Aronsson (1999), Crettez (2004) Dissou, Mac Leod, and Souissi (2002), Faehn and Holmoy (2003) Nordhaus and Yang (1996), Proost and Van Regemorter (1992), Rasmussen (2001), Kumbaroglu (2003), Roson (2003) , Uri and Boyd (1996) and Vennemo (1997). Despite so many studies there apparently very few studies that measure and demonstrates the level of pollution as a consequence of multisectoral dynamic general equilibrium process in UK. More particularly this study shows how taxes in the use of labour and capital inputs in production could be used to control such pollution and to show the effects of such measure on the growth, investment and capital accumulation in the next eighty years UK economy. The dynamic multisectoral and multi-household general equilibrium model of energy and environmental taxes for the UK (GEMEETUK) is further development from Bhattarai (2010, 2007,2005, 2003, 1999).

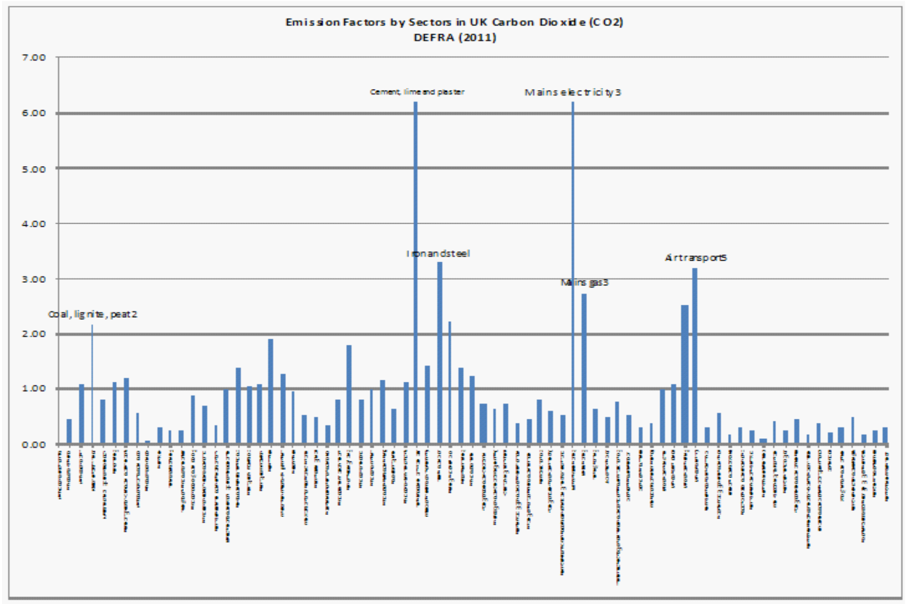
Large scale dynamic models are able to trace the impact of policy changes on investment and saving activities in accumulation and growth rates of capital stocks that determined output, employment and functional distribution of income in those sectors. Expansion of economy improves living standards as reflected in the growth rate of utilities for each categories of households. These activities also raise the level of pollution which negatively affects the economy. The GEMEET model aims to measure the damage that occurs to the economy from pollution resulting as a consequences of consumption and production process. Emissions from electricity generators, factories, vehicles, aircrafts and ships and submarine transports contribute to global warming and resulted in unprecedented environmental catastrophes including hurricanes, soil erosions, floods, draught and deforestation. These cumulatively lead to degradation in the quality of lives of human and animal, birds and sea animals over the coming years. In a recently published Carbon Plan UK government is committed to cut such emissions by 34% by 2020 and 80% by 2050.

Table 1: Sources of Green-House Gas (GHG) Emission in UK

	Percentage
Electricity Generation	35
Household Consumption	14
Industry and Business	17
Transport	22
Waste	3
Agriculture	8
Public Sector	3
Total	102

Economists together with natural scientists have attempted to assess the amount of damage of such encroachment into environment using dynamic general equilibrium models of one or multiple economies with proper appreciation of interactions among them (Nordhaus (DICE-1993); Perroni and Rutherford (1993), Nordhaus and Yang (Rice -1976); Hope and Newberry (2008) ,Grubb, Jamasb and Pollit (2008)). The pollution generated in this manner affects not only the national economy but has global consequences (Stern (2007, 2008)). This study aims to provide an assessment on such consequences based on a fairly decentralised market economy model benchmarked to the micro-consistent data contained in the most recent input-output table for the UK economy.

Capital stock at any point of time is result of the investment undertaken over years and such investment is possible from savings made by households who sacrifice current consumption in anticipation of higher rate of consumption in future years. An economy where the choices and activities of households are well coordinated over time can generate higher amount of capital stock compared to



one that cannot coordinate such activities because of inefficient financial system and hence lags behind in the process of accumulation and growth. Right set of policies can lead to environment friendly growth and wrong policies produce harmful pollutants, perhaps at a faster rate than that of capital. A dynamic model with many households and firms is a right tool to investigate these important issues.

The GEMEETUK model includes ten categories of households differentiated by their levels of income who decide on consumption, labour-leisure and savings considering their life time budget constraints and preferences. The major objective of each household is to maximise their life time utility subject to its time and capital endowments. Investors, in each period of the model, allocate investment across sectors looking at the marginal productivity of capital among industries making sure that more productive sectors get more investment than less productive ones. Economy is open to trade with the rest of the world, either with requirement that the trade need to balance in each period or on the intertemporal basis. The government collects direct and indirect taxes to provide for public consumption or to transfer some of it to low income households. By Walras' law relative prices change until the demand equals supply in all goods and factor markets for each period and for the entire model horizon.

2 General Description Of The Model

A general equilibrium model is a complete specification of the price system in which quantities and prices are determined by the interaction of both demand

and supply sides of goods and factor markets. It can be applied to measure consequences of economic policy on growth, accumulation and pollution over time and also to determine how a government can influence market outcomes by distorting the equilibrium prices by means of taxes and transfers. It can show how the labour leisure choice of households and employment level of firms, growth rate of output, employment and capital and the investments occurs through the optimization process of households, firms and traders and how one set of policies can be more efficient than others in generating the optimal levels of utility for all households leading to just and best social welfare result for the economy.

2.1 Preferences

Various specifications of utility functions are used to represent the level of welfare of households from consuming goods and services and leisure in an economy. Time separable constant elasticity of substitution (CES) utility function with three levels of nests is used here to capture the intra- period and inter temporal substitution between consumption and leisure based on relative prices and wage rates in the economy. The first level of nest aggregates the goods and services in composite consumption good, then the second level nest aggregates these composite goods with leisure. Then there is the nest of time separable utility functions to arrive at the life time utility for each household. Pollution reduces household utility as households pay for its abatement. The consumption shares of various goods are calibrated from the benchmark dataset (see Barker, Blundell and Micklewright (1989) for more in depth study on demand side parameters of household demand functions).

2.2 Production technology

A production technology shows how inputs are transferred into outputs. Usually labour, the human toils and trouble in process of production; capital, the man made means of production, as reflected in building, structures including highways, communication networks and education, health and environmental system; natural resources including clear air, water, and mineral and energy products represent such inputs. In addition there are intermediate inputs as presented in the 123 sector input output table. Intensity of use of these factors in a specific industry or a firm is reflected by a production function, the CES categories of these functions being the most commonly used ones in the economic literature as they capture the cross price elasticity more efficiently than any other linear or Cobb-Douglas production functions.

2.3 Trade arrangements

It is well known from the time of Ricardo that an economy benefits from trade by exporting products in which it is more efficient and by importing ones in which its comparative advantages are minimal. In a free trade regime the volume of trade is significantly influenced by the efficiency of production technology of firms and preferences of households for the domestic and foreign products. Such preferences implicitly determine the elasticity of substitution and transformation between domestic and foreign products as well as the terms of trade among trading partners.

2.4 Government sector

Government receives revenues from direct and indirect taxes and tariffs. These taxes affect the marginal first order conditions for optimal conditions of demand and supply functions for efficient allocation of resources for consumption, production and trade. The government may strategically adopt a number of policies adopting the balanced or deficit or cyclically balanced budget and get debt levels tied to the certain percentage of GDP as fixed by international treaties relevant at that time. Which one of the tax instruments is optimal and most efficient source of revenue may partly depend on preferences of households and the size of the government in economic activities.

2.5 Definition of equilibrium for a growing economy

Equilibrium is a point of rest, where the opposing forces remain in balance. Theoretically there has been much work, since the time of Adam Smith in Walras-Arrow-Debreau-Hahn-McKinzie for finding whether it exists, or is unique or is stable along with analysis of Pareto efficiency for a centralised or decentralised economy. In theory the existence of equilibrium or Walras' law is proved using a unit simplex and Brouwer's or Kakutani's fixed point theorem in which the uniqueness is guaranteed by the choice of preferences and technology and trade functions that fulfil continuity, concavity or convexity or twice differentiability properties. In applied policy work, numerical methods are adopted to find the solutions of these models as the explicit analytical solutions are possible only for very small scale models that hardly represent highly complicated mechanism in a modern economy.

Dynamic general equilibrium is essentially a system of relative prices of commodities, factors of production such as wage rate and interest rate that balance demands and supplies for each product or factor of production in the market for each period as well as for the entire model horizon. When a model is properly calibrated to the benchmark micro-consistent data set, such prices reflect the degree of scarcity and desirability for those goods in the economy that balance cost and benefits to the suppliers and consumers in the economy.

An economy may not always be in competitive equilibrium. Imperfections either in goods and input markets are common and monopolistic or oligopolistic situations arise. Numerical model pick up such imperfections by the mark-ups over cost covering prices though these can further require considerations of strategic interactions at various fronts between consumers and producers, firms and government or between the national economy and the Rest of the World, each player in the game is trying to shift the burden of pollution or taxes onto others creating discreteness or non-convexities in opportunity sets making it harder to find the equilibrium even though that may exist in the system.

2.6 Nature of policy experiments

Even a small distortion or reform in policy for a particular sector, such as the electricity, can have a large impact on the growth of other sectors or welfare of households over time when that is well integrated through the positive or negative externalities to other sectors of the economy. Policies aim to find the best society given the preferences and technical possibilities and constraints need to look at detrimental impacts of pollution and good impacts of positive externalities before determining the best action among all available alternatives. The general equilibrium model, like the current one, can act as a policy where these various possibilities can be tested and their impacts be measured.

3 Specification of Key Functions in the GEMEE-TUK Model

Households solve the inter-temporal allocation problem by maximising the lifetime utility subject to their lifetime budget constraint as:

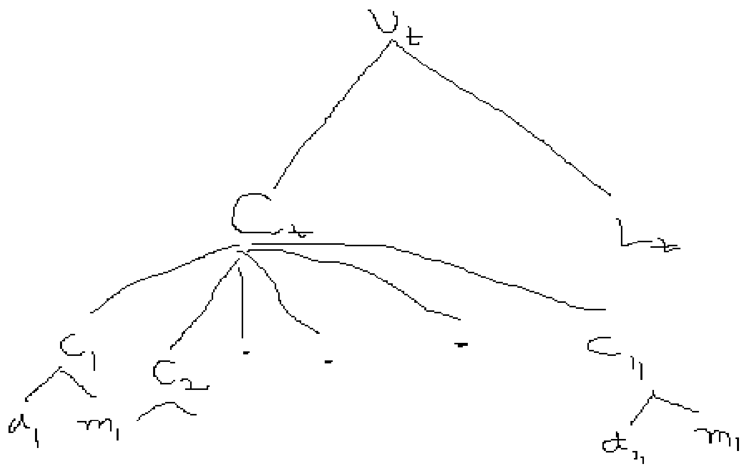
$$max\ U_0^h = \sum_{t=0}^{\infty} \beta^{t,h} U_t^h \left(C_t^h, l_t^h\right) - \sum_{t=0}^{\infty} \psi EM_t^h \tag{1}$$

Subject to

$$\begin{aligned} & \sum_{t=0}^{\infty} R_t^{-1} \left[P_{i,t}\left(1+tc_i^h\right) C_{i,t}^h + w_t^h \left(1-tw^h\right) l_t^h + PP_t EM_t^h\right] \\ = & \sum_{t=0}^{\infty} \left[w_t^h \left(1-tw^h\right) LS_t^h + r_t \left(1-tk\right) K_t^h + TR_t^h\right] \end{aligned} \tag{2}$$

where U_0^h is lifetime utility of the household h, $C_{i,t}^h$, l_t^h and LS_t^h are respectively composite consumption, leisure and labour supplies of household h in period t, PP_t is the price of pollution abatement, EM_t^h is the amount pollution burden in household h $R_t^{-1} = \prod_{s=1}^{t-1} \frac{1}{1+r_s}$ is an objective discount factor whereas β is the subjective discount factor of consumer for future consumption relative current consumption; r_s represents the real interest rate on assets at time s; tc_i^h is value added tax on consumption, tw^h is labour income tax rate, and K_t^h the capital endowment of household h, P_t is the price of composite consumption (which is based on goods' prices), i.e $P_t = \varphi \prod_{i=1}^{N} \alpha_i^h p_{i,t}^h$, and C_t^h is the composite consumption, which is composed of sectoral consumption goods,$C_t^h = \prod_{i=1}^{N} \alpha_i^h C_{i,t}^h$.

Nested Structure of Consumption and Utility



Industries of the economy are represented by firms that combine both capital and labour input in production and supply goods and services to the market to maximise their profits:

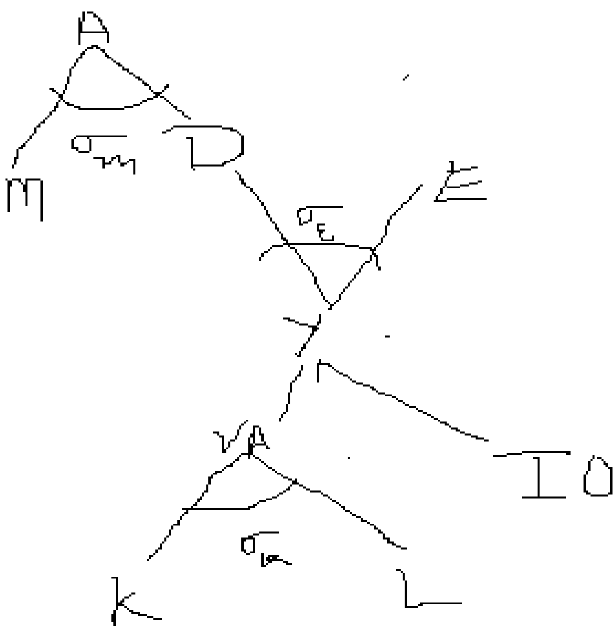
$$
\begin{aligned}
max \;\; \Pi_{j,t} \;\; = & \;\; \left(\left(1-\delta_i\right) PD_{j,t}^{\frac{\sigma_y - 1}{\sigma_y}} + \delta_i PE_{j,t}^{\frac{\sigma_y - 1}{\sigma_y}} \right)^{\frac{1}{\sigma_y - 1}} \\
& -\theta_i PY_{j,t} - \theta_i^d \sum_{t=0}^{\infty} a_{i,j} P_{i,t} - \theta_i^m \sum_{t=0}^{\infty} a_{i,j}^m P_{i,t} \qquad (3)
\end{aligned}
$$

where: $\Pi_{j,t}$ is the unit profit of activity in sector j; $PE_{j,t}$ is the export price of good j; $PD_{j,t}$ is the domestic price of good j; $PY_{j,t}$ is the price of value added per unit of output in activity j; σ_y is a transformation elasticity parameter ; $P_{i,t}$ is the price of final goods used as intermediate goods; δ_i is the share parameter for exports in total production; θ_i is the share of costs paid to labour and capital; θ_i^d is the cost share of domestic intermediate inputs,(θ_i^m for imported intermediate inputs); $a_{i,j}^m$ are input-output coefficients for domestic supply of intermediate goods.

This is an open economy model in which goods produced at home and foreign countries are considered close substitutes by Armington assumption, popular in the applied general equilibrium literature. The production, trade and supply processes by sectors is easy to comprehend with a four level nests of functions for each as in Figure 1.

Households pay taxes to the government, which either it returns as transfers to low income households and spends rest of it to pay for public consumption.

Nested structure of production and trade in GEMEETUK



$$
\begin{aligned}
REV_t \quad = \quad & \sum_{i=1}^{N}\sum_{h=1}^{H} t_{i,t}^{k} r_t K_{i,t}^{h} + \sum_{i=1}^{N}\sum_{h=1}^{H} tc_i^h P_{i,t} C_{i,t}^{h} + \sum_{i=1}^{N} t_i^{gv} P_{i,t} G_{i,t} \\
& + \sum_{i=1}^{N} t_i^{vk} P_{i,t} I_{i,t} + \sum_{i=1}^{N} t_i^{p} P_{i,t} GY_{i,t} + \sum_{i=1}^{N} t_i^{m} PM_{i,t} GY_{i,t} \\
& + \sum_{h=1}^{H} r_t t_k K_t^h + \sum_{h=1}^{H} w_t^h tw^h LS_t^h
\end{aligned}
\tag{4}
$$

where REV_t is total government revenue and is a composite tax rate on capital income from sector i, tc_i^h is the ad valorem tax rate on final consumption by households, t_i^{gv} is that on public consumption and t_i^{vk} is the ad valorem tax rate on investment, tw^h is the tax rate on labour income of the household, t_k is the tax on production, and t_i^m is the tariff on imports.

The steady state equilibrium growth path of the economy is determined by relative prices of goods and factors such as the rental rate and the interest rate, that ultimately depend on parameters of the model such as subjective and objective discount factors, elasticities of substitution and many other shift and share parameters. By Walras' law these prices eliminate the excess demand for goods and factors. These conditions emerge from the resource balance and zero profit conditions for the economy and for each household and for the government and for the rest of the world sectors in each period as well as over the entire model horizon. Government tax and transfers policies can alter this equilibrium. Income of each type of household evolves over time as a function of the relative prices of goods and share of households in total endowment of capital and labour.

The production process releases emissions that manifests itself in the forms of air, water, land and noise pollutions. Pollution is a by product of production process. This is included by an emission function in the model as following:

$$
EMIS_t = \sum_{i=1}^{N} \phi_i Y_{i,t} \tag{5}
$$

where $EMIS_t$ represents the total amount of emission and ϕ_i is the pollution coefficient for industry i the rate of pollution generated in producing output $Y_{i,t}$. It is assumed to remain constant for this model. Higher rate of pollution is harmful for growth and hence for the welfare of households. While the consumption of goods generates utility to the households and such pollution generates negative externality. Their utility level falls with the increased amount of emission as it effectively reduces households' life time income.

4 Calibration to the Benchmark Reference Path

The dynamics in this model arise from an endogenous process of capital accumulation and exogenous growth rate of the labour force. We rule out uncertainty in aggregate and rely on the perfect foresight of households and firms, which means that actual and expected values of variables are the same.

There are essentially five steps involved in calibration of this dynamic model. The first step relates to forming a relation between the price of investment good at period t,P_t and the price of capital in period t+1, P_{t+1}^k. It also needs specifying a link between prices of capital stock at periods t and $t+1$, $P_t^k$and P_{t+1}^k, with due account of the rental on capital and the depreciation rate. For instance, one unit of investment made using one unit of output in period t produces one unit of capital stock in period t+1. This implies,$P_t = P_{t+1}^k$, where P_t is the price of one output in period t and is the t period P_{t+1}^kprice of one unit of capital in period t+1.

Capital depreciates at the rate of δ. One unit of capital at the beginning of period t earns a rental and delivers (1-δ) units of capital at the end of period t (or at the start of the t+1 period), $(1-\delta_i)\,P_{i,t+1}^k$. Here R_t^k, is also measured in term of P_t^k or P_{t+1}^k .We therefore must have:

$$P_{i,t}^k = R_{i,t}^t - (1-\delta_i)\,P_{i,t+1}^k \tag{6}$$

In a perfect foresight world price of capital in period t really reflects the sum of discounted rental over time.

The second step of calibration involves setting up a link of the rental rate with the benchmark interest rate and the depreciation. The rental covers depreciation and interest payment for each unit of investment. When rental is paid at the end of the period

$$R_{i,t}^t = (r+\delta_i)\,P_{i,t} = (r+\delta_i)\,P_{i,t+1}^k \tag{7}$$

where r is the benchmark real rate of interest.

Thirdly step of calibration involves forming relation between the future and the current price of capital. Use equation (6) and (7) together to get

$$\frac{P_{i,t+1}^k}{P_{i,t}^k} = \frac{1}{1+r_i} \approx (1-\delta_i) \tag{8}$$

This means that the ratio of prices of the capital at period t and t+1 equals to the market discount factor in the model, which is $(1-\delta_i)$. This discount factor can also be approximated by $\frac{1}{1+r_s}$.

The fourth step of calibration involves setting up equilibrium relation between capital earning (value added from capital) and the cost of capital. We compute values for sectoral capital stocks from sectoral capital earnings in the base year. If capital income in sector i in the base year is $\overline{V}_{i,t}$, we can write $\overline{V}_{i,t} =.R_i\ K_{i,t}$.Thus investment per sector is tied to earnings per sector. Since the return to capital must be sufficient to cover interest and depreciation, we can also write

$$\overline{V}_{i,t} = (r + \delta_i) P^k_{i,t+1} K_{i,t} \ ; \ \ K_{i,t} = \frac{\overline{V}_{i,t}}{r_i + \delta_i}; \quad P_{i,t} = P^k_{i,t+1} \tag{9}$$

The fifth step of calibration involves setting up relation between the investment and capital earning on the balanced growth path. Investment should be enough to provide for growth and depreciation, $I_{i,t} = (g_i + \delta_i) K_{i,t}$, which together with (9) implies

$$I_{i,t} = \frac{g_i + \delta_i}{r_i + \delta_i} \overline{V}_{i,t} \tag{10}$$

The balance between investment and earnings from capital is restored here by adjustment in the growth rate g_i that responds to changes in the marginal productivity of capital associated to change in investment. Readjustment of capital stock and investment continues until this growth rate and the benchmark interest rates become equal.

If the growth rate in sector i is larger than the benchmark interest rate then more investment will be drawn to that sector leading to an increase in the capital stock in that sector. By the process of diminishing return to capital more investment eventually will lower growth rate of that sector eliminating the excess returns that attracted investment in the beginning. In the benchmark equilibrium, all reference quantities grow at the rate of labour force growth, g, and reference prices are discounted on the basis of the benchmark rate of return as given by equation (8) above.

5 Microconsistent Benchmark Data Set

The model is calibrated using the eleven sector micro-consistent input-output table of the UK economy published by the Office of National Statistics (ONS); more detailed 123 sector results are not reported due to space limitation. Income distribution data among households obtained form the Department of Works and Pension and the tax rate information gathered from the Inland Revenue, Custom and Excise. The data set has been prepared to calibrate the model to the steady state. Elaticities of substitution in consumption and production are based on values generally accepted in the literature.

Input-output table shows backward and forward linkage in the economy. The sectoral value added including payment to labour, capital and taxes and final demand for consumption, investment, exports and government spending along with imports are also obtained from the input output table.

The distribution of income and consumption among households is at the centre of the current analysis.

Table 2: Input-Output Transaction Table

	Agri	Min	Manu	Utils	Const	Dist	Trans	Fin	Pub	Edu	Other
Agri	2940	2	12343	10	300	2000	76	18	0	314	50
Min	8	5135	27093	28873	2919	231	93	17	0	9	58
Manu	8151	3156	201896	5038	33839	52652	25289	16992	24756	36983	8324
Utils	627	1028	12487	26717	358	2633	1159	2147	1502	2626	811
Const	280	767	1062	720	63570	1928	2332	15293	5313	1254	755
Dist	772	165	1537	322	2040	8050	3831	7284	2029	2937	838
Trans	554	1425	15657	475	1616	35310	42631	29243	5731	6692	3109
Fin	2827	3986	38205	4798	27691	66029	32720	193292	25082	27671	21538
Pub	12	31	648	58	487	283	2209	8536	318	105	91
Edu	217	59	1417	237	222	1166	1360	6448	5368	39424	1164
Other	328	166	3749	221	205	2230	2112	5362	3766	4386	19106
Total Y	38395	89608	1076724	88320	231540	153318	223947	812625	139001	297069	128219

Table 3: Benchmark production tax rate, prices income and demand by sectors

	Captax	Labtax	price	Wages	Capital	Cons	Inv	Gov	Exp	Imp	Total Y
Agri	-0.1454	-0.7864	0.2136	4488	8091	16948	5779	0	2226	8842	38395
Min	-0.0118	–0.3005	0.6995	3914	33116	279	23654	0	23709	36142	89608
Manu	0.3361	0.3728	1.3728	107901	39898	364299	28499	0	229788	314342	1076724
Utils	0.0038	0.0250	1.0250	6249	13825	35989	9875	0	195	569	88320
Const	0.1145	0.3092	1.3092	41994	37817	7766	27012	0	1288	1169	231540
Dist	0.1954	0.2690	1.2690	119477	54821	112601	39158	0	10537	15552	153318
Trans	-0.0176	-0.0238	0.9762	62387	28087	55913	20062	0	24252	21631	223947
Fin	0.0633	0.2505	1.2505	179913	237423	212562	169588	0	119742	50575	812625
Pub	0	0	1.0000	55509	9581	4057	6844	118263	1162	46	139001
Edu	0.0236	0.0120	1.0120	145204	24662	56117	17616	181380	2434	2470	297069
Other	-0.0165	-0.0262	0.9738	42155	22367	61495	15976	14401	7572	9327	128219

The multisectoral model presented here demonstrates how the relative prices and quantities interact in the economic system. Such interactions occur through complicated process of intertemporal and intra-temporal income and substitution effects. Expansion or contraction of a certain industry affects not only the employment and output and prices of its own but also have widespread circulatory impacts on upstream and downstream sectors. Growth in one sector pulls the growth rate of the other sectors, through the process of backward and forward linkages contained in the input-output system and inter-linked markets in the economy through accumulation and substitution processes both in consumption and production sides of the economy.

Level of production in each sector respond to final demand for products of that sector by households, firms government or the ROW and that generates the demand for labour and capital inputs. The level of income of households changes

Table 4: Benchmark production tax and prices by sectors

Deciles	Income share	Income tax rate	Consshare	Leisure	Consumption
H1	0.0281	-0.15	0.0314	10480	58156
H2	0.0433	-0.05	0.0474	14756	51239
H3	0.0551	0.25	0.0563	13424	57902
H4	0.0669	0.35	0.0667	14117	67738
H5	0.0789	0.35	0.0787	16656	78619
H6	0.0908	0.35	0.0905	19161	89677
H7	0.1081	0.35	0.1078	22821	99009
H8	0.1276	0.35	0.1257	24858	11440
H9	0.1521	0.40	0.1499	29644	130799
H10	0.2493	0.40	0.2456	48576	180481

Table 5: Consumption of households by sectors in UK, 2008

Deciles	Agri	Min	Manu	Utils	Const	Dist	Trans	Fin	Pub	Edu	Other
H1	476	8	10221	1010	218	3159	1569	5964	114	1574	1725
H2	733	12	15762	1557	336	2419	2419	9197	176	2428	2661
H3	934	15	20076	1983	428	3081	3081	11714	224	3093	3389
H4	1133	19	24361	2407	519	3739	3739	14214	271	3753	4112
H5	1337	22	28742	2839	613	8884	4411	16771	320	4427	4852
H6	1538	25	33064	3266	705	10220	5075	19292	368	5093	5581
H7	1832	30	39380	3890	839	12172	6044	22978	439	6066	6648
H8	2162	36	46470	4591	991	14363	7132	27114	518	7158	7844
H9	2578	42	55416	5475	1181	17128	8505	32334	617	8536	9354
H10	4225	70	90807	8971	1936	28067	13937	52984	1011	13988	15329
Total Y	38395	89608	1076724	88320	231540	153318	223947	812625	139001	297069	128219

in response to changes in capital and labour income and changes in household income translate into the change in final demand. This completes the first circle and if economy is allowed to function automatically with any rigidities this initaites other rounds of knock on effects until the economy converges to the inter-temporal equilibrium. Shocks or reforms in one sector transmit to other sectors and have large cumulative impacts in the economy, which can be quite large.

In addition to information on benchmark prices and quantities, the numerical implementation of the model requires information on shift, share, elasticity and policy parameters defining various equations in consumption and production sides of the economy. Values of key parameters used for computation of the current model are given in Table 5. This set of parameters possess desirable properties required for well behaved demand and supply functions that guarantee the existence, uniqueness and stability of equilibrium. Sensitivity tests are used to test the robustness of model results to different values of these parameters.

Table 6: Key Parameters of the Model

	values
Elasticity of substitution	1.15
Steady state growth rate	0.03
Benchmark interest rate	0.05
Intertemporal substitution	0.95
Rate of depreciation	0.02
VAT rate	0.20
Elasticity of transformation	2.00
Capital labour substitution	1.5
Armington substitution	1.2
Emission rate	0.01

6 General Equilibrium Impacts of Pollution Abating Taxes on Capital, Output and Growth

Scientifically pollution - carbon dioxide, methane, nitrogen dioxide or nitric oxide, chlorofluorocarabon (CFC)) in solid, liquid or gaseous form or the explosive, oxidizing, irritant, toxic, carcinogenic, corrosive, infectious, teratogenic, mutagenic hazardous solid wastes - is detrimental to human, animal of plant lives. It not only contaminates and adulterates the natural environment and ecological balances locally but has global consequences resulting in the rise of temperature, acid rains, a large Arctic ozone hole ultimately generating a process called the "greenhouse effect". Despite that it is hard to quantify the damage caused by such pollution and putting energy and environmental taxes might be not be a prudent way of controlling such pollution. Using applied general equilibrium models Whalley and Wigle (1991) had estimated consequence of 50 percent reduction in CO_2 gases to cause up to 19 percent reduction in GDP, Vennemo (1997) showed carbon taxes caused a fall in the wage rate of up to 5 percent, Kombaroglu (2003) reported them to dampen the growth rate by up to 6 percent, Bohringer, Conrad and Loscel (2003) found negative impacts of such taxes on output, employment and the wage rate, Perroni and Rutherford (1993) had shown how pollution permits would affect the structure of trade among economies. Economists however have paid little attention to the form of social pollution that affects mainly service industries. Corruption, sleaze, malpractices, breach of fundamental human rights and social values create tensions, anxieties, social conflicts and reduce the creativity and productivity of workers and utility of households though it is very hard to quantify impacts of these externalities.

This section focuses on reporting results from a representative model with eleven sectors and ten households for a model horizon on 82 years with particular focus on the impacts of energy carbon taxes on the level and growth rates of capital accumulation, employment, output, investment by sectors, the level of welfare by ten categories of households, and economy wide impacts in terms of key macro economic variables with a numbers of interconnected graphs constructed from the results of the model. More detailed results for 123 sector were computed but not reported due to space limitations.

Imposition of extra environmental and energy taxes to reduce the pollution affects the behaviour of households and firms. Taxes reduce the profitability of firms, therefore they invest less and have less capital stock and they produce less. Taxes depress the real income of households and their levels of utility despite working more. These affect macroeconomic scenarios and allocations and impact on redistribution. There is still a great deal of uncertainty about the optimal rate of carbon tax even after several years of intense research activity on carbon taxes, global warming (Poterba (1993), Stern (2008)).

7 Impacts By Sectors

Growth of capital stock, output and investment in the agriculture sector,- that includes farms crops, livestock, forestry, and fisheries- is lower than in the benchmark when taxes are imposed in the use of inputs. Scientifically it is true that the malpractices in agriculture can generate biomass, organic and inorganic wastes that cause environmental problems and hazards to human and animal health which may result from animal manure and other dejections, animal corpses, residues of plastic, rubber and other petrochemicals, pesticides, pharmaceuticals, papers and wood, mineral fertilizer, scrap tools and agricultural machines. Nitrous oxides generated by these processes can bring respiratory infections, burning of eyes, headache, chest tightening, ground water pollution and inadequate measures taken to control the spread of crop or animal diseases can produce biological hazards. It is questionable, whether extra tax for controlling such pollution in this manner is reasonable as the most of agricultural wastes can be valuable resources if properly recycled with adoption of better agricultural recycling practices. More taxes in input merely deter farmers from spending on better environmentally friendly production technology.

Extra taxes reduce the growth rate of output, investment and capital stock in the mining sector. It is well understood that pollution emerging from physical and chemical processing of minerals in metal ores extraction as well as other mining and quarrying sector may generate acids and drilling mud, dangerous substances, land deformation which can be minimised by designing dumping sites for sulfidic waste specific materials with proper consideration of climate, hydrogeological conditions to prevent air penetration and water infiltration rather through higher rates of input taxes.

Accumulation of capital stock, output, and investment is affected by extra taxes in the manufacturing sector relative to the benchmark. At the current state of technology manufacturing is not possible without burning fossil fuels directly from machines operating from burning such fuels or indirectly through use of electricity that is generated through CO2 releasing fossil fuels. This is evident from a cursory look at the composition of 45 different industries such as meat processing, fish and fruit processing, oils and fats, dairy products, grain milling and starch and animal feed, bread, biscuits, etc, sugar, confectionery, other food products, alcoholic beverages, soft drinks and mineral waters, tobacco products, textile fibres, textile weaving, textile finishing, made-up textiles, carpets and rugs, other textiles, knitted goods, wearing apparel and fur products, leather goods, footwear, wood and wood products, pulp, paper and paperboard, paper and paperboard products, printing and publishing, coke ovens, refined petroleum & nuclear fuel, industrial gases and dyes, inorganic chemicals, organic chemicals, fertilisers, plastics & synthetic resins etc, pesticides, paints, varnishes, printing ink etc, pharmaceuticals, soap and toilet preparations, other chemical products, man-made fibres, rubber products, plastic products, glass and glass products ceramic goods, structural clay products, cement, lime and plaster, articles of concrete, stone etc , iron and steel, non-ferrous metals, metal castings, structural metal products, metal boilers and radiators, metal forging, pressing, etc; cutlery, tools etc, other metal products, mechanical power equipment, general purpose machinery, agricultural machinery, machine tools, special purpose machinery, weapons and ammunition, domestic appliances, office machinery & computers, electric motors and generators etc, insulated wire and cable, electrical equipment, electronic components, transmitters for TV, radio and phone receivers for TV and radio, medical and precision instruments, motor vehicles, shipbuilding and repair, other transport equipment, aircraft and spacecraft, furniture, jewellery and related products Sports goods and toys, miscellaneous manufacturing & recycling that rely very much on fossil fuels. Despite continuous efforts for adopting more efficient and environmental friendly production technologies over years, production plants of these industries are known for generating pollutants such as CO2, S2 or other hazardous gases as by-products in the production process, ever since the time of industrial revolution. Environmental or energy taxes can only raise the cost of production and lower their motivation to search for better technology.

Growth of capital, output and investment in the energy sector - that includes production and distribution of electricity and gas - are affected negatively by extra input taxes. Electricity is generated from coal, oil, gas, wind turbines and nuclear sources. Coal and oil plant generate larger amount of CO2 in atmosphere and the nuclear sources are difficult to build in the beginning and leave plenty of hazardous wastes at the end. If one looks at the current industrial structure of the energy sector, environmentally friendly renewable sources can not fulfil even a fraction of energy demand and this industry is in needs of support for better technology such as carbon tapping, development of hydrogen and other sources of green energy, extra taxes can only cause a setback .

The growth of capital, output and investment in the construction sector is relatively higher than in other sectors mainly because of higher taxes in the use of input in this sector in the benchmark.

The distribution sector here consists of motor vehicle distribution and repair, automotive fuel retail, wholesale distribution, retail distribution, hotels, catering, pubs etc. Improper scrapping of old vehicles generates solid waste, cold-storages and refrigeration generates CFC and improper treatment of residues at the retail level causes pollution. Again extra taxes slightly lower the growth of output, capital and investment compared to the steady state.

Transport and communication sector comprises of railway transport, other land transport, water transport, air transport, ancillary transport services, postal and courier services and telecommunications generates air, water, noise and land pollutions. Extra environmental taxes raise cost of operating their businesses and depress the growth of capital, output and investment in this sector. Better technology rather than taxes can promote the growth of this sector.

The business service sector represents banking and finance , insurance and pension funds , auxiliary financial services, owning and dealing in real estate, letting of dwellings, estate agent activities, renting of machinery etc, computer services, research and development , legal activities, accountancy services, market research, management consultancy, architectural activities and technical consultancy ,advertising and other business services. Negative externality in this sector may be less visible; intense competition for market often generates rivalry, spam, fraud and unhealthy practices that can put extra costs of providing services. It is difficult for any tax system to prevent such malpractices. Higher rates of taxes reduce its growth compared to the benchmark.

The other services sector includes public administration and defence, education, health and veterinary services, social work activities, membership organisations, recreational services, other service activities, private households with employed persons and sewage and sanitary services. Malpractices in social services sector appear in the form of corruption, sleaze, unfair treatment and breach of fundamental liberties, trust and social values which may cause anxiety and create psychological burden and create an unhealthy environment for workers as well as entrepreneurs in the economy. It requires more creative thinking and putting extra taxes creates disincentives and cannot contribute to higher productivity required for growth prospect of this sector.

8 Conclusion

An attempt has been made here to evaluate the economy wide impacts of changes in pollution taxes imposed on use of capital and labour inputs on the capital accumulation, on growth rates of output, employment and investment sectors and income, utility and welfare by households and on the allocation of scarce economic resources across production sectors and among households and the government in the UK economy benchmarking the model to data on income for ten categories of households and eleven production sectors aggregated most recently from 123 sector input-output table of the UK economy. Results demonstrate very important role of investment and saving and capital accumulation process in the evolution of the economy. Insufficient growth rate of capital, caused by higher rate of energy and environmental taxes on use of labour and capital income can slow down the growth rate of output across all sectors and reduce the level of welfare of households. Environment and energy taxes not only slow down the rate of accumulation and growth but also make households worse off than compared to policies in base as usual scenarios. Mechanism for pollution control should rely on energy saving technological enhancement or energy efficiency measures at the household or industry levels and better waste management techniques as outlined in the Carbon Plan (2010) than relying on energy and environmental taxes.

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