The Economic Impact of Health Care Provision: A Preliminary CGE Assessment for the UK[1]

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1. Introduction

This paper presents some preliminary results from a CGE model of the interactions between government-provided health care and the outputs of non-health goods and national welfare in a small open economy. The effects on welfare of higher health provision come through two main channels: (a) the direct gain from increasing the 'well-being' of the population, and (b) the indirect effects of an increase in the size of the *effective* (i.e. 'able to work') endowments of skilled and unskilled labour for use in non-health activities. A higher level of health provision enlarges effective labour supply in the short term by augmenting the aggregate working time of current workers (including wastage by premature death). It does so in the longer term by reducing death rates among those young who are destined to enter the work force. However, it also increases the number of people who are not part of the work force (the young and the retired).[5] These are an additional source of demand for health services, so reducing availability and/or level of treatment for the current work force and so reducing its effective size. Moreover, both groups of non-workers are usually recipients of transfers from the working population (e.g. state benefits for children, state pensions for the retired), with the associated distortions.

We believe the analysis is innovative in two respects. First, there have been few applied studies of the general equilibrium effects of illness/healthiness on the non-health economy. Nearly all health economics modelling is done in a partial equilibrium setting, and as such tends to focus on the impact of policy on current and prospective patients. Rationalisations for the partial equilibrium approach include the relative smallness of the health sector and the high degree of specialisation (i.e. intersectoral immobility) of highly skilled staff and high-

1 We are grateful to Rod Falvey, Doug Nelson and Dave Whynes for their helpful comments and suggestions. The responsibility for any remaining errors or infelicities remains with us.

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5 The dominant users of health care are those under 5 years of age, those over 60, and the 'long-term ill' (according to the ONS (2002) some 850 million workdays are lost each year through 'incapacity', representing 2.3 million people or approximately 3.8% of the population in the UK.)

tech capital. While these may hold true, there are other strong interactions with the rest of the economy and with policy-making, certainly in the longer term, so that it is arguable that a general equilibrium modelling may be more appropriate for the analysis of some issues. With respect to the labour market, the majority of health sector staff, even the part that is skilled, is in practice inter-sectorally mobile (managers and associated staff, laboratory technicians, ancillary workers). Thus expansion or contraction of the health sector will impact on other sectors. Some sectors will expand while others contract, depending on the relative factor-intensity of the health sector. Similar comments apply to sectors producing intermediate inputs for the health sector (pharmaceuticals, high-tech equipment).

Second, while there is a strong literature on endogenous labour supply models (e.g. Martin, 1976, Martin and Neary, 1980), these have in the main been based on direct labour supply response to higher wages. In this model, changes in the effective supply of skilled and unskilled labour come from changes in the size of health provision (which in this UK-centred example is determined by the government). Whether these changes in factor supplies increase some sectoral outputs and decrease others, or increase all outputs depends on whether the 'scale effect' of increased factor supplies outweigh the 'factor-bias' effect of changes in the ratio of skilled to unskilled labour.

Using a CGE model we find that an increase in public health expenditures increases the health of skilled and unskilled labour which, once allowing for positive health effects on effective labour supply, enhances welfare up to 10 billion pounds (compared to a deterioration of 0.6 billion pounds when health effects are absent). A surprisingly low degree of effectiveness of health care in increasing labour market participation rates suffices to ensure a welfare gain. With health effects absent, public health care and sectors producing intermediate inputs (pharmaceutical industry and medical, precision and optical instruments) expand, whereas private health care and other non-health sectors contract (private health care faces higher input costs). Skilled labour benefits from inter-sectoral reallocations whereas unskilled labour and capital remunerations fall. The introduction of increasingly strong positive health effects eventually leads to increases in the production of all sectors, implying that the scale effect dominates factor bias effects. As labour becomes relatively less scarce wages fall and rents rise.

We also simulate a rise in the price of pharmaceuticals under a scenario in which the government maintains a fixed health budget – such that public health care treatment levels must fall – and a scenario in which the government allows its health budget to grow with the aim of maintaining previous treatment levels under the NHS. In the first scenario levels of public and private health care provisioning fall due to a rise in the costs of inputs. Health deteriorates and – allowing labour supply changes conditioned on health – labour market participation falls. Overall welfare falls up to 2.255 billion pounds. When the government increases public health care expenditures so as to maintain previous treatment levels, negative health and welfare effects are mitigated; and welfare falls up to 1.233 billion pounds.

Distributional effects of the counterfactual simulations are unequal across labour categories and household types. Skilled labour at all times is worse off in terms of employment relative to unskilled labour as some of the skilled consume public *and* private health care, the latter becoming more costly and less available. Households with working members gain from higher levels of health provision through increased participation in the labour market, whereas non-working households, who are solely dependent on benefits from the state, lose.

An important lesson learnt from all model experiments is that results differ in the short run, i.e. when health effects are absent, and the long run, when health effects materialise. Increasing or maintaining levels of NHS care in the short term implies crowding out savings and investments or foregoing other expenditures, in this model transfers to households, and hence leads to welfare losses. In the long term, when positive health effects emerge, such policies pay off and may lead to substantial welfare gains depending on the effectiveness of health care in improving effective labour supply. They do so by increasing the labour market participation of the working population and by enhancing the tax earning ability of government, which benefit both working households (in terms of wage income) and non-working households (in terms of transfer income).

The rest of the paper is organised as follows. Section 2 presents a literature review of CGE models applied to health care. Section 3 uses standard diagrammatic analysis for a low dimension general equilibrium model to provide some insight into the effects of changes in health provision on employment and production in non-health sectors. Section 4 gives a brief overview of government provision of and policy towards health care in the UK. Section 5 discusses the data used in the calibration of the CGE model and the structure of the model itself, and section 6 presents and discusses the results of some counterfactuals. Finally, section 7 offers some conclusions and discusses planned future work.

2. Review of CGE models of changes in health and health provision

Applied literature focusing on general equilibrium effects of changes in health and health care on the economy is small but diverse in terms of application area. The earliest type of models that acknowledge the economy-wide effects of improved health, Basic Needs models,[6] were designed to implement the basic needs approach to development of the 1970s into a comprehensive framework, with its overarching goal of basic needs satisfaction. Health and health policy fulfil only a minor role and it has proven virtually impossible to disentangle the effect of improved health within counterfactual simulations. Furthermore, Basic Needs models typically are recursive dynamic, applied to developing countries and by virtue of the latter, suffer from lack of data, a rather ad hoc approach to modelling of economic behaviour and abstraction from several general equilibrium elements (such as endogenous prices and government budget).

Externality models account for the presence of external effects, such as health, education and environmental effects, in a CGE framework. To our knowledge only one CGE model of health externalities exists, that by Savard and Adjovi (1997).[7] Health improvements appear in the form of improved labour productivity by implementing labour-augmenting technological progress in production (as a function of government expenditures on health relative to the base year) which influences the optimal combination of inputs in production and relative wages. The main aim of the model, and indeed of most externality models, is to verify whether the standard CGE result of (small) economic benefits from trade liberalisation holds in the presence of positive health and education externalities. The conclusion is negative as cuts in government expenditure on health and education, aimed at maintaining the government deficit, have negative spill-over effects on domestic product and public sector employment, household income and welfare. In contrast to Basic Needs models, this model is firmly grounded in microeconomic optimisation behaviour and accounts for various inter-sectoral linkages, however, it too is applied to developing country issues in which health is only of secondary importance. Further caveats are a lack of dynamic effects, no distinction

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[6] Vianen and Waardenburg (1975) focus entirely on health care (in Tanzania) and model the working time effect of improved health by postulating that the number of people recovering or dying is a function of the number of treatments, next to those who recover spontaneously. In van der Hoeven's (1987, 1988) Kenyan model health is restricted primarily to affect demographic variables. Kouwenaar's (1987) model for Ecuador also includes a labour productivity effect via labour augmenting technological progress.

[7] A selection of environmental CGE models featuring side effects on health care are: Vennemo (1997), Beghin et al. (1999), Bruvoll et al. (1999), Garbaccio et al. (2000) and Li (2002).

between working and non-working or age groups, and absence of endogenous labour supply effects (i.e. the impact of better health on working time).

The most recent class of models of HIV/AIDS[8] assess the economic impact of HIV (Human Immunodeficiency Virus) and AIDS (Acquired Immune Deficiency Syndrome) using (recursive) dynamic CGE analysis. Generally, this literature models the negative health consequences of the pandemic by imposing exogenous demographic and behavioural scenario's on the economy. Typical features of the pandemic are that it reduces labour supply by skill type, factor productivity, and increases household and government expenditures on health care at a cost of expenditures on other goods and savings. Under these assumptions the literature's main finding is that the slow-down in physical capital accumulation (due to lower savings and investments), productivity growth, population growth and human capital accumulation (due to a fall in supply and demand for education) reduces economic growth and results in a fall in per capita income in the long term compared to a fictional "No-AIDS" scenario. Relative to Basic Needs and Externality models, HIV/AIDS models are relatively sophisticated in the sense that they model the various channels through which changes in health, albeit negative, affect the economy in greatest detail. Nevertheless, and most likely due to the incurable nature of the disease, the HIV/AIDS studies abstract from any positive feedback effect from health (and other) expenditures to population health and labour supply.

A related strand of Health Sector models[9] claims to be of the general equilibrium type, but since the model domain spans health care markets only and abstracts from the "rest of the world" they are truly partial in nature. These models are typically applied to developed countries and feature the behaviour of patients, general practitioners, medical specialists, pharmacists, drug producers (brand name and generic), parallel importers, insurance companies and hospitals and the various interrelationships between them. Special attention is devoted to the presence of market failures such as information asymmetries between patients,

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[8] Kambou, Devarajan and Over (1992) implement the impact of HIV/AIDS on the Cameroonian economy by reducing growth rates for labour supply by skill type. Arndt and Lewis's (2000, 2001) South African model incorporates a variety of demographic and behavioural effects (household and government responses to palliate the negative consequences of the pandemic). The impact of the HIV/AIDS pandemic on the rate of skill accumulation via reductions in education spending is assessed by Arndt and Wobst's (2002) Tanzanian model and Arndt's (2003) model for Mozambique.

[9] Chatterji and Paelinck (1991) develop a purely theoretical general equilibrium model. Canton and Westerhout (1999a, b) and Folmer et al. (1997) construct models applied to the Dutch pharmaceutical and health care market respectively, which are employed to analyse financial reform measures.

physicians and pharmacists (principal-agency problems) and imperfect competition in the market for pharmaceuticals caused by patenting. Although the detailed level of analysis of medical care represents a constructive addition to the previously discussed CGE studies, their partial character precludes general equilibrium analyses such as resource claims of health care (i.e. competition for scarce factors of production such as capital and labour), government budget implications and the impact on effective labour supply of improved health, which are crucial for our understanding of the economic impact of health provision.

From the foregoing analysis we conclude that, although the labour productivity effect of improved health is well-established, none of the reviewed models (Basic Needs models, Externality models, HIV/AIDS models and Health Sector models) have assessed the impact of changes in health provision on the size and composition of the population, the labour force and its impact on production, income and welfare over time. In this paper we attempt to model the endogenous labour supply, i.e. working time, effect of changes in the quantity of health care provided, while recognising the resource claims made by the health sector in terms of capital and, more importantly, labour inputs.

3. Effective labour endowments and the health sector: some low-dimension analytics

Consider a small open 'Heckscher-Ohlin' economy, endowed with two types of labour, skilled (*S*) and unskilled (*U*) both subject to illness at given rates. There are four sectors ('uses' for factors): *X* and *Y* are conventional tradables, *H* is the non-tradable health sector treating the ill (modelled as adding value to the ill), *W* is the 'sector' recording those that become ill and are not (successfully) treated by the health sector (the 'waiting list') and are so unable to work. We assume that health care is provided by the government and that its expenditure is determined politically (and so exogenously to this model). The exogenous product prices determine the factor prices and hence skilled-unskilled ratios in the three production sectors.

Within the period concerned, numbers S_I and U_I of skilled and unskilled workers become ill (unable to work). However, the health service successfully treats all but S_W and U_W of these (the loss of working time for those successfully treated is taken, for simplicity of exposition, as negligible). Accounting for factor use (paralleling the full employment conditions for conventional models) gives

$$S_X + S_Y + S_H + S_W = S \qquad (1a)$$

$$U_X + U_Y + U_H + U_W = U \qquad (1b)$$

We are interested in the *effective* labour forces, S_E and U_E, where

$$S_E = S - S_W \tag{2a}$$

$$U_E = U - U_W \tag{2b}$$

and S_W and U_W are the numbers of potential workers that remain unable to work.[10]

Figure 1 shows one possible initial equilibrium. It is drawn on the assumptions that (a) the health sector is the most skill-intensive sector, and the Y sector the least skill-intensive, that the incidence of illness is the same for both groups of workers,[11] and that the health sector allocates its output of health treatment in proportion to the numbers of each labour type becoming ill.

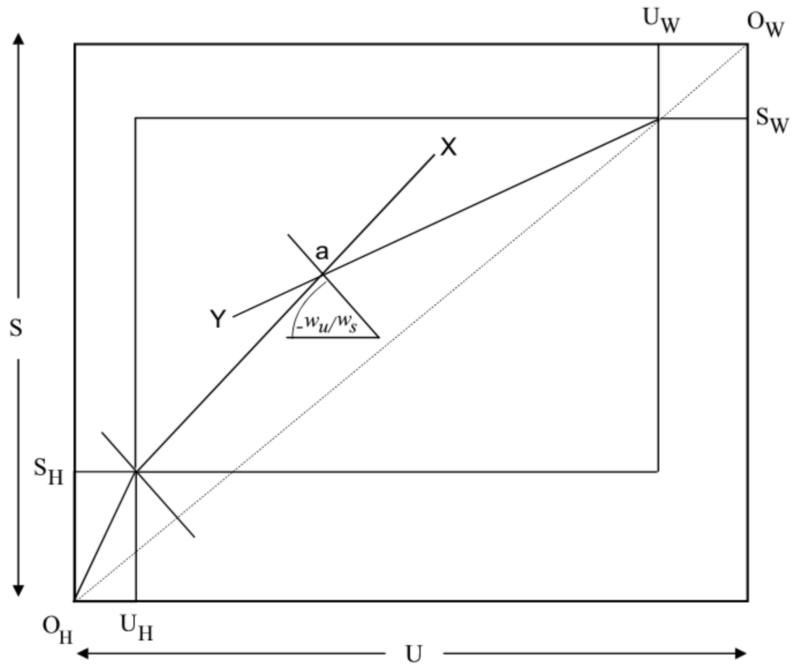

Figure 1: An initial equilibrium

The maximum possible endowments of skilled and unskilled labour are S and U respectively.[12] Inputs into the health sector are measured from O_H, while those unable to work are measured from O_W. The government health budget purchases S_H and U_H of labour inputs at wages w_S and w_U. At that level of health provision the numbers of potential workers remaining on the 'waiting list' are S_W and U_W (and by virtue of the previous

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10 This is a question of scaling. We could equally well work in terms of the numbers of 'worker-hours' lost. It is more convenient to discuss the issues in terms of 'workers'.

11 There is evidence that the incidence of illness is higher in the low-income groups, but we ignore this for simplicity of exposition.

12 In the sense that there is no ill health, and hence no need for health provision.

assumptions are in the same proportion as the economy's endowment ratio). The inner box then gives the skilled and unskilled labour available to work in the two tradables sectors. Measuring inputs into the X sector from the north-east corner of the 'health' box and inputs into the Y sector from the south-west corner of the 'waiting list' box allows us to determine the equilibrium allocation at point a.

Figure 2 illustrates the consequences of the government increasing the health budget in the case where there is no change in the overall endowments. Inputs of skilled and unskilled labour in the health sector increase to S_H^* and U_H^* respectively. The provision of extra health care reduces the numbers on the waiting lists to S_W^* and U_W^*.

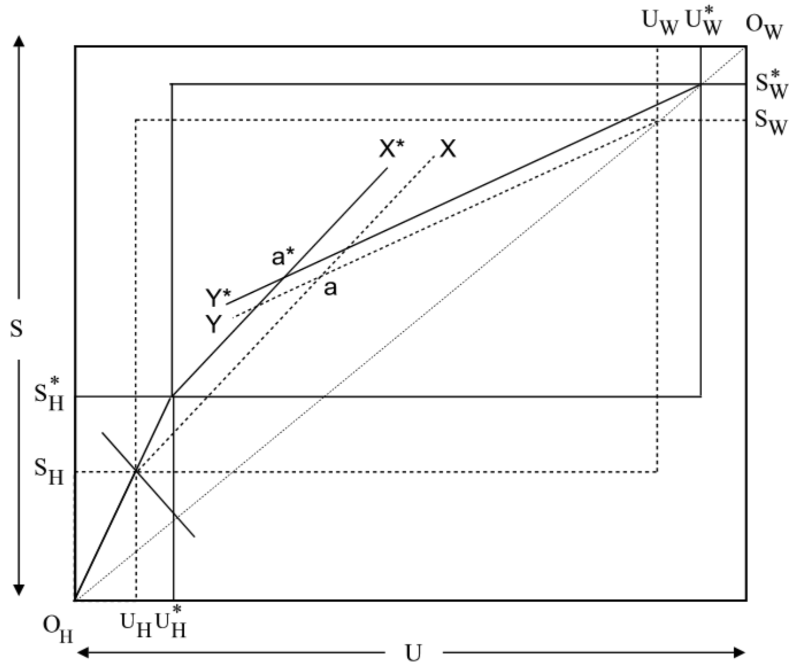

Figure 2: Expansion of the Health sector with unchanged endowments: example 1

The expansion of the health sector and the contraction of the waiting list changes both the total amounts of factors available to the two tradables sectors and the relative skilled-unskilled ratio. It is convenient to decompose these into a 'scale effect' (increasing both effective factor endowments by the lower of the two actual increases) and a 'factor-bias' effect (increasing the effective endowment of the higher-growth factor). Splitting the changes into the two components allows us to draw some insights from standard trade theory results.[13] Since the health sector is, in this example, the most skill-intensive sector, its expansion will

[13] These results have their origin in the seminal paper by Rybczynski (1955).

lead to a contraction of the X sector due to the reduction in the availability of both factors, compounded by a reduction in the ratio of skilled to unskilled workers available to the tradables sectors. The effect on the output of the Y sector will be a mix of contraction due to the reduced availability of both labour types and expansion due to the reduction in the ratio of skilled to unskilled workers. In the Figure 2 example it is evident that the net effect is a contraction of the X sector and an expansion of the Y sector.

However it will also be evident that in general the effects on the tradables sectors depend on the ordering of factor intensities of the three production sectors and the endowment ratio, and on the incidence of illness and of the provision of treatment for the two types of labour.

For example, Figure 3 shows a case where the health sector is smaller than the waiting list sector (both having the same factor intensities as in Figure 2), but with the health sector having much greater 'leverage' on the size of the waiting list sector.

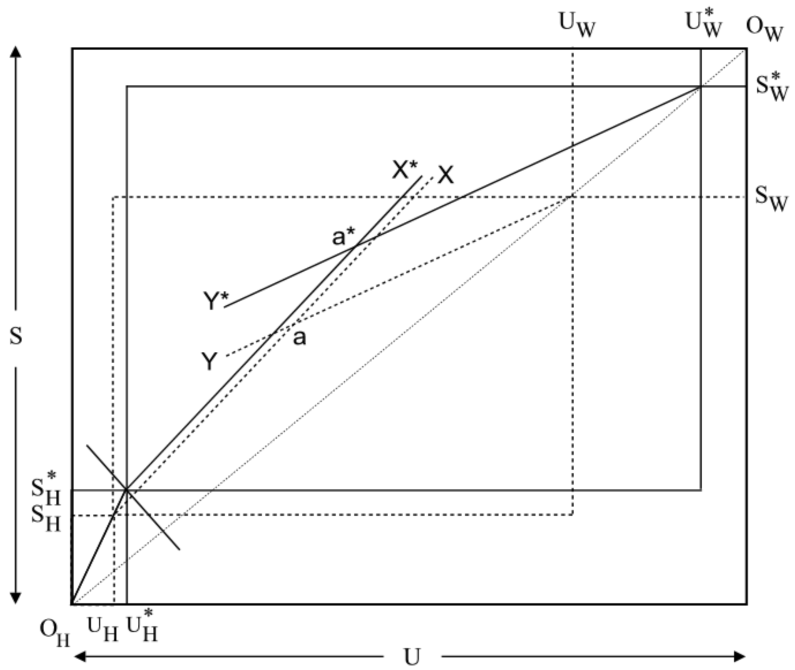

Figure 3: Expansion of the Health sector with unchanged endowments: example 2

Here the 'scale effect' dominates the 'factor-bias' effect: the former leads to an increase in the outputs of both tradable goods, and the increase in the output of the X good from the former is greater than the decrease in X output due to the 'factor-bias' effect (which also leads to a further increase in Y output). Thus outputs of both tradables increase.

Whether the health sector is, in fact, more skill-intensive than all other sectors is an empirical question, as is that of whether the incidence of illness and the provision of health care are both independent of labour type. In a multi-sectoral model with more than two factors the foregoing predictions are most unlikely to be wholly true. Nevertheless, they give a useful guide to the interpretation of the outcomes of such a model.

4. The UK health system and health policy

The UK health system is dominated by state provision via the National Health Service (NHS) (devolved to regional health authorities with responsibility for hospitals, general practitioners and ancillary services). There is some private provision via insurance schemes that use private facilities, but also buy facilities and skills from the state sector. Private provision is mostly of secondary (hospital) care and covers approximately 12 per cent of cases. (All NHS medics working in the secondary sector have contracts that allow them to provide private treatment, some 75 per cent doing so, and many NHS facilities are available for hire by private providers.)

Financial provision for the NHS is set by the government over a five-year planning period, and the responsible department (the Department of Health) must bid for a share of the overall budget in competition with departments responsible for the armed forces, education, law enforcement etc.. The NHS administration itself works to a rolling three-year planning horizon, and may seek marginal adjustments to state finance on an annual basis.

UK governments (of both major political parties) have been exercised by the escalating costs of the NHS. They have some control of some inputs, (e.g. salaries of staff, working practices, capital provision) but less control of others (e.g. pharmaceuticals prices). More importantly, they are faced with longer-term problems such as the increasing longevity of population and the demand for the use of new, and usually more costly, technologies.

Evidence of pressure on secondary treatment facilities is provided primarily by the length of the 'waiting lists' for treatments – the so-called 'rationing by delay' policy operated by the NHS. Some non-life-threatening complaints are subject to long delays before treatment, and the existence of such queues may in itself act as a disincentive to seek treatment. As part of its longer term strategy the NHS also 'rations by denial' in blocking, or at least delaying, the adoption of new technologies.[14]

[14] The fear is that if a new, superior, technology is approved then there will be a significant increase in demand, whereas if it is not available then patients 'will not miss what they don not have'. This is analogous to the effects on recruitment of 'firing costs' discussed in the labour economics literature; see for example Garibaldi (1998).

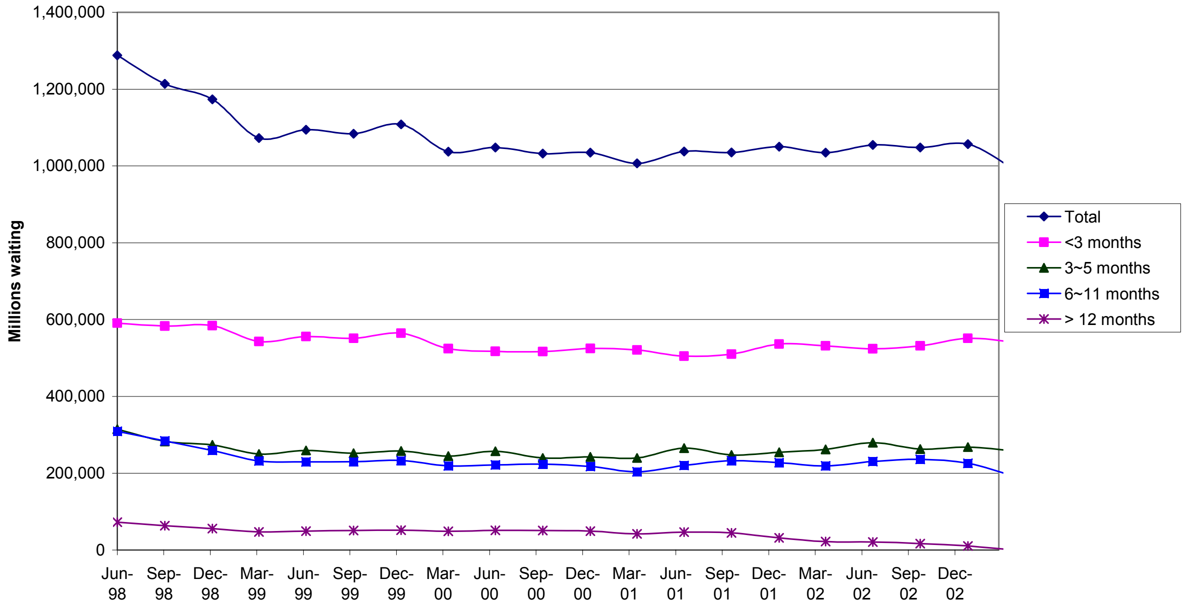

Figure 4: In-patient waiting lists (ordinary and day case admissions), England[15]

Government policy on medical procedures and associated inputs does not always focus on 'best' provision, even within existing technologies. For example, empirical evidence suggests that some surgeons use procedures that lie well above the lower envelope of existing efficient cost-outcome procedures.[16]

The UK government's unwillingness to tackle the more intractable inefficiencies in the system (e.g. working practices), coupled with the (political) necessity of restricting costs, has led them to focus on more controllable costs. In parallel with (generally successful) efforts to restrict medical salaries, maintain current working practices, etc, the government has sought to limit the ever-increasing cost of pharmaceuticals.[17] The chosen instruments have been to negotiate price agreements with providers and to require doctors to prescribe only from approved lists of drugs[18] – mostly 'generic' products which, being 'out of patent', are cheaper (but arguably less effective).

Nevertheless, prices of pharmaceuticals are not within direct government control. Therefore, an increase in the price of drugs poses problems for the government. The extreme options are to: (a) maintain the official budget expenditure, implying a reduction in expenditure on other

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[15] Hospital Inpatient Waiting List Statistics, England, NHS Trust based, the 'Green Book', available from http://www.doh.gov.uk/waitingtimes/booklist.htm (accessed 18-08-2003).

[16] The Health Technology Assessment unit in the UK and the National Institute for Clinical Excellence in the USA seek to identify and promote best practice.

[17] As do the governments of most countries.

[18] The UK government operates a system of 'black', 'grey' and 'white' lists of pharmaceuticals.

treatment costs (numbers treated, time spent in hospital), or (b) to expand the budget at the cost of offsetting cuts elsewhere and so reductions in other government-provided goods.

5. The database and the CGE model

The CGE model is a single-country comparative static model of the UK economy calibrated to 2000 data. The SAM underlying the model is derived from the UK Supply and Use Balances for 2000,[19] other national accounts sources, and the General Household Survey (GHS) 2000-2001.[20] The structure of production, output, demand and trade are taken from the supply and use balances, which provide a commodity-by-industry use matrix for 123 commodities and industries which are aggregated to eleven sectors for the purposes of this analysis (among which public and private health care, the pharmaceutical industry and a sector producing medical, precision and optical instruments). A commodity-by-industry make matrix is derived from data on industry and commodity output in 2000 and the most recent published make matrix for the UK, for 1990. The GHS is used to disaggregate labour payments into two types (skilled and unskilled) and to provide data on five household types (pensioners, non-working households with and without children and working households with and without children). The UK National Accounts 'Blue Book'[21] is used to ensure that household aggregates are correct.

The model employs standard assumptions regarding perfect competition, constant returns to scale and simultaneous market clearing. The Harberger convention is used throughout, so that the model is calibrated so that all prices are equal to one in the benchmark. Production and consumption behaviour are modelled using the constant elasticity of substitution (CES) family of functions, which includes Leontief, Cobb-Douglas and constant elasticity of transformation (CET) functions. Cross-border trade is treated under a set of commonly used assumptions. Firstly, the UK is treated as a small open economy, implying that the UK faces exogenous world prices for imports and exports. Secondly, products are differentiated

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[19] Available from the homepage of the Office for National Statistics (ONS), National Statistics Online: http://www.statistics.gov.uk/statbase/Product.asp?vlnk=7640&Pos=1&ColRank=1&Rank=272 (accessed 18-08-2003).

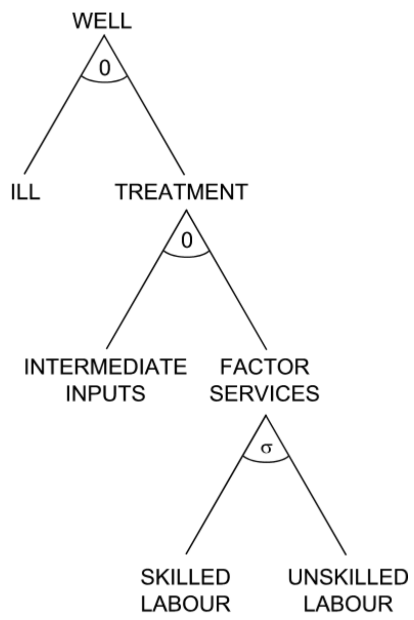
[20] The GHS is carried out by the Social Survey Division of the ONS collecting information on a range of topics from people living in private households in Great Britain. The complete dataset is available from the UK Data Archive (UKDA): http://www.data-archive.ac.uk (accessed 18-08-2003). The ONS and UKDA bear no responsibility for the analysis or interpretation of the data as laid out in this paper.

[21] Available from National Statistics Online: http://www.statistics.gov.uk/STATBASE/Product.asp?vlnk=1143 (accessed 18-08-2003).

according to region of origin according to the familiar Armington assumption, so that imports and exports are qualitatively different from domestically produced goods.

It seems a reasonable simplification to model health provision as a non-tradable output (using traded intermediates) that adds value to the ill, who are treated as an intermediate input.

Figure 5: Modelling Health Provision



The given health budget limits inputs of factor services and intermediates, usually to a level insufficient to treat all those presenting themselves as ill. The output WELL is thus, in terms of people, less than the input ILL. The WELL output could be viewed in two ways: (a) it is the number of people treated and 'cured', the remainder being added to the waiting list; or (b) it is the proportional reduction in the degree of illness of all groups, with the proportion of 'semi-cured' workers becoming an addition to the effective workforce.

In this paper we report on a comparative statics analysis, the easiest formulation. The obvious gains from this approach are that we need not model longer-term population processes (births, deaths, transitions from YOUNG to WORKING and from WORKING to RETIRED), nor do we have to model the decomposition of those moving from YOUNG to WORKING into SKILLED and UNSKILLED. The major disadvantage is that we have to 'translate' the health transition from ILL to WELL, which is less than 100% in a dynamic framework, into a one-period model. However, an offsetting advantage is that we can gain insights into the implications of policy changes from our earlier low-dimension analytical model.

We model the interaction between health and labour supply in the static CGE model by the use of a non-participation rate η_i for each type of labour. Non-participation can be interpreted as being on the waiting list, whereas participation implies employment in one of the sectors of the economy. The effective labour supply LS_i is then a function of labour endowments LE_i and the non-participation rate:

$$LS_i = LE_i(1-\eta_i) \qquad 0 \le \eta_i \le 1 \qquad i \in F \qquad (3)$$

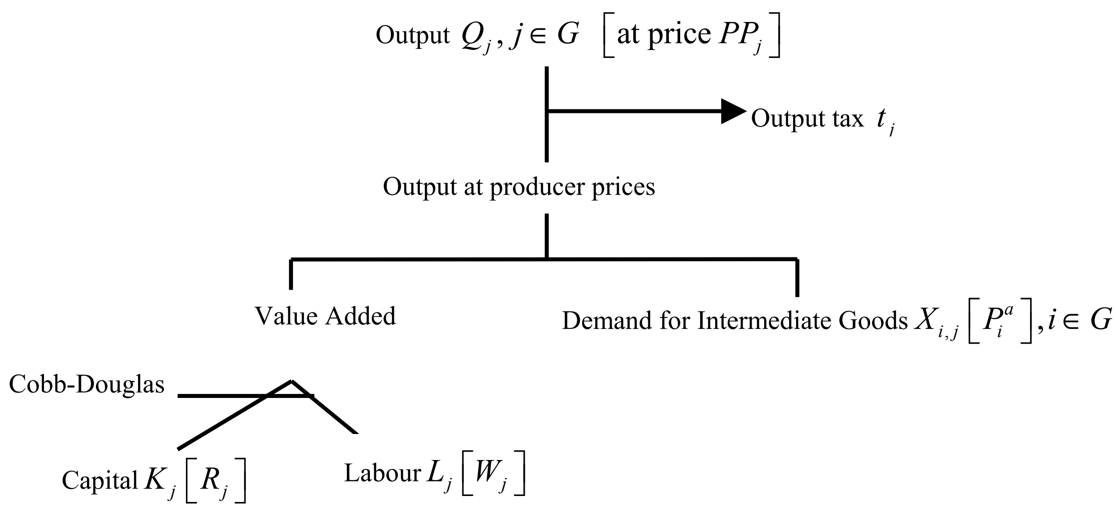
The non-participation rate η_i, is formulated as a constant elasticity function of the level of health, *H:*

$$\eta_i = \gamma_i H_i^{-\beta} \qquad \beta \ge 0, \gamma > 0 \qquad i \in F \qquad (4)$$

γ_i is calibrated so that the benchmark levels of health provision lead to the required non-participation rate.[22] It measures the effectiveness of the level of health, such that a reduction in γ_i, given H_i, reduces the non-participation rate and increases effective labour supply. The parameter β is an elasticity that determines how non-participation rates respond to changes in health provision (i.e. it measures the effectiveness of changes in health). $\beta = 0$ implies that no such response occurs, and will be used as one of a number of possible values of β in the reported simulations.

The level of health depends on the level of public and private health provision Q_{NHS} and Q_{PHC}:

Figure 6: The nested production function



$$H_i = Q_{NHS}^{\alpha_i} Q_{PHC}^{(1-\alpha_i)} \qquad 0 \le \alpha_i \le 1 \qquad i \in F \qquad (5)$$

α_i is a parameter specifying, for each labour type i, what proportion of health is determined by public as opposed to private health provision.[23]

The structure of production in each of the eleven sectors is shown in Figure 6. For each sector in the set of produced goods G, a multi-stage production function is specified in equations (6). The zero-profit condition is given in equation (7). Production is taxed at an *ad valorem* rate t_j, and is a Leontief function of value added and inputs of intermediate goods. Value added is a Cobb-Douglas function of labour and capital inputs.

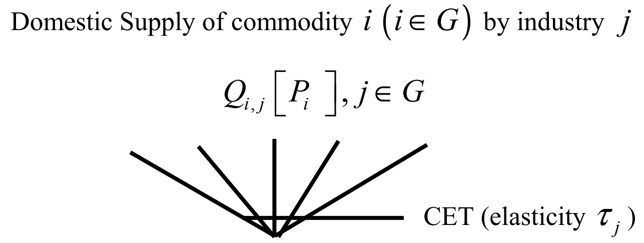
$$Q_j = \frac{1}{\left(1-\bar{t}_j\right)} \min\left[CD\left(E_{i,j} i \in F\right), X_{i,j} \, for \; i \in G\right] \qquad j \in G \qquad (6)$$

$$Q_j PP_j = \frac{1}{\left(1-t_j\right)}\left[\sum_{i \in F} E_{i,j} W_i + \sum_{i \in G} X_{i,j} P_i^d\right] \qquad j \in G \qquad (7)$$

Output of each sector Q_j is transformed into supply of each commodity as shown in Figure 7. Equation (8) shows that production by sector j is a CET function of the production of individual commodities i by sector j, $Q_{i,j}$. Equation (9) gives the zero-profit condition for commodity supply.

$$Q_j = CET\left(Q_{i,j}; \tau_j\right) \qquad j \in G \qquad (8)$$

Figure 7: Output transformation

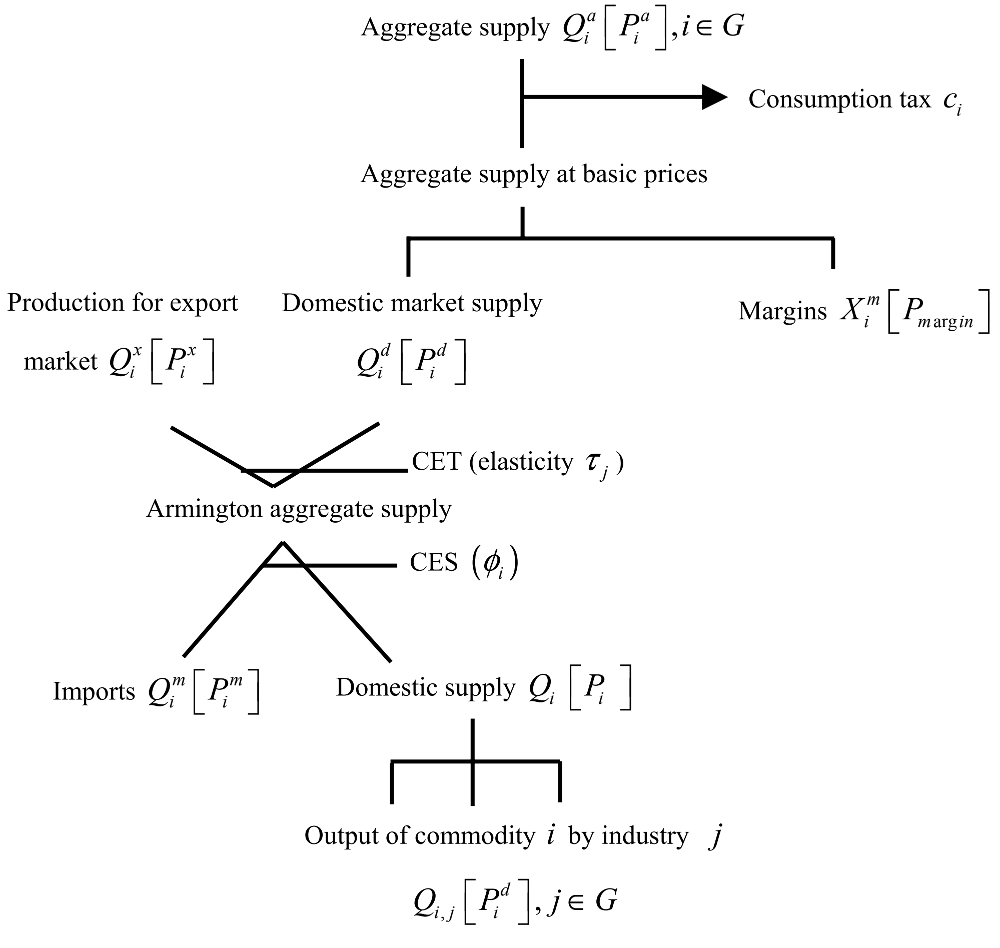


[22] The non-participation rate for skilled and unskilled labour in the benchmark is 10%.

$$Q_j PP_j = \sum_{i \in G} Q_{i,j} P_i \qquad j \in G \qquad (9)$$

Figure 8 shows the structure of market supply. Imports Q_i^m and domestic supply Q_i^m (which is the sum of each industry j's output of commodity i, $Q_{i,j}$) are aggregated according to the Armington assumption (goods are differentiated according to their origin), with a CES function defining the substitution possibilities between imports and domestic goods. Aggregate supply is then divided into export supply Q_i^x and supply to the domestic market Q_i^d (equations (10) and 9). Equations 10 and 11 show how domestic market supply is transformed into aggregate supply at basic prices by the addition of transport and trade margins. Equation (14) is the equilibrium condition in goods market, where aggregate supply is equal to the sum of intermediate demands from different industries plus the sum of demands by different households, demand by the government, export demand and investment demand.

Figure 8: Market Supply



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[23] We assume that unskilled labour (i.e. those on low income) has access to public health care only, $\alpha_{unskilled} = 1$.

$$CET\left(Q_i^x, Q_i^d; \tau_i\right) = CES\left(Q_i, Q_i^m; \phi_i\right) \quad (10)$$

$$Q_i^x P_i^x + Q_i^d P_i^d = Q_i^m P_i^m + Q_i P_i \quad (11)$$

$$Q_i^a = \frac{1}{1-c_i} \min\left[Q_i^d, X_i^m\right] \qquad i \in G \quad (12)$$

$$Q_i^a P_i^a = \frac{1}{\left(1-c_i\right)}\left[Q_i^d P_i^d + X_i^m P_{margin}\right] \qquad i \in G \quad (13)$$

$$Q_i^a = \sum_{j \in G} X_{i,j} + \sum_{j \in H} X_{i,j} + X_{i,GOV} + X_{i,XPT} + X_{i,INV} \qquad i \in G \quad (14)$$

Six representative agents in the model consume goods and services: five private households and government. The private households (denoted by the set H) and government are demonstrated in Figure 9.

Each of the five households receives income from capital (being the sum of incomes from a variety of sources, from ownership of firms to interest on savings or pensions), and government transfers. The pensioner household and the two ‘working’ households receive income from employment, in proportion to their earnings from unskilled and skilled labour endowments. Each household pays direct taxes on labour and capital income, and spends its disposable income on the eleven commodities and on savings.

Equation (15) gives private disposable income Y_i.

$$Y_i = \sum_{j \in F} LS_{j,i} W_j \left(1 - t_j\right) + T_i \qquad i \in H \quad (15)$$

The remainder of public and all private health care is consumed by skilled labour ($\alpha_{skilled} = 0.84$).

Equation (16) gives the definition of private expenditure E as a function of private savings and private expenditures. The real level of savings is given in equation (18) as a function of demands for savings, which is equal to output of investment, a function of investment demands for individual commodities. Equation (19) equates the value of savings with the value of investment demand for individual commodities. Equation (20) equates net income with expenditure.

$$E_i = Q_i^s P^s + \sum_{j \in G} X_{j,i} P_j \qquad i \in H \qquad (16)$$

$$U_i = CES\left(X_{SAV,i} X_{j,i} \ j \in G; \rho\right) \qquad i \in H \qquad (17)$$

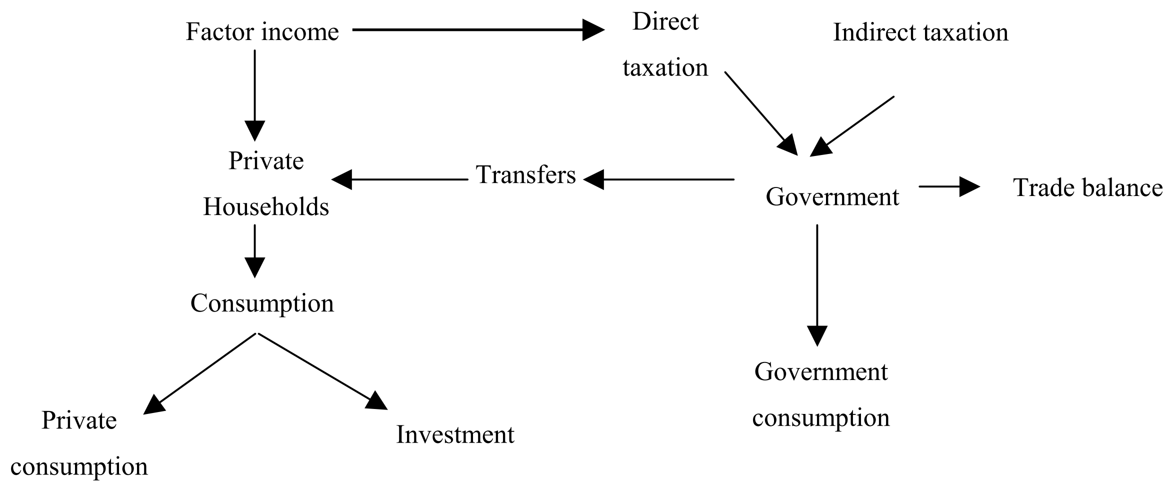
$$Q^s = \sum_{i \in H} X_{SAV,i} = f\left(X_{i,INV} for \ i \in G\right) \qquad (18)$$

$$Q^s P^s = \sum_{i \in G} X_{i,INV} P_i \qquad (19)$$

$$Y_i = E_i \qquad i \in H \qquad (20)$$

The government receives income from indirect and direct taxation, consumes three commodities ('health', 'public administration and defence' and 'other services') and purchases a fixed small amount of foreign exchange in order to finance the trade surplus. It

Figure 9: The private household and government



transfers the remainder of its income to the five households, in proportion to their original income from government benefits in the original data. This constitutes the government 'closure' rule in the model. Other closure rules are that net foreign investment is fixed, and therefore the trade balance is also fixed, and investment is savings-driven.

The model is solved in MPSGE with the exchange rate set as the numéraire. Welfare results are derived for each household as the equivalent variation of private household utility U. Overall welfare changes are computed as the sum of household equivalent variations plus the change in the government's provision of public goods (health services).

6. The counterfactual simulations

In order to illustrate the functioning of the model and potential application areas we perform two simulations.

Firstly, we consider the effects of a 10% increase in expenditures on the NHS in a scenario of perfectly mobile factors of production (experiment 1). The expansion of public health care, although drawing away resources from other sectors in the economy, is expected to improve health, labour market participation and welfare. Secondly, we simulate a 10% increase in the market price of pharmaceuticals under a scenario in which the government keeps its (overall) health budget fixed in value (experiment 2) and one where the government increases expenditures on NHS health care, such that total real government expenditures on health care are unchanged (experiment 3). In the first scenario, the increase in the cost of pharmaceutical inputs implies lower levels of health care provisioning and that less people are receiving treatment, and, hence, deterioration in health, lower labour market participation rates, lower (working) households' incomes and a fall in overall welfare. We expect that negative effects on health, labour market participation and welfare will be mitigated in the second scenario as the government increases expenditures on health care and so maintains the previous level of health care provisioning, i.e. number of treatments, under the NHS.

A sensitivity analysis is carried out to check the robustness of results for the health elasticity parameter β. Results are reported for $\beta=0$ unless indicated otherwise; these experiments give the direct effects of additional expenditure on health sector employment and output but suppress the indirect effects coming through, for example, increased labour market participation.

Experiment 1: a 10% increase in public health expenditures – perfectly mobile factors

Government expenditures are fixed in foreign exchange terms, so that the immediate effect of an expansion of public health expenditures in the face of given tax revenues is to reduce transfer payments to households by 5.17%. The additional NHS resources result in an increase in public health care provision by 9.94% and, via input-output linkages, increase the demands and production of pharmaceutical products (by 5.01%) and medical, precision and optical instruments (by 1.71%). As a result health care, pharmaceuticals and instruments become relatively more expensive (domestic prices increase by 0.055%, 0.035% and 0.043% respectively,) which increases the costs and hence reduces the size of private health care provision (by 0.94%), all remaining sectors contract.

In the trade balance, the major changes occur in the health-related sectors: imports of pharmaceuticals rise by 4.69%, exports rise by 4.61%. Imports and exports of medical, precision and optical instruments increase by 1.61% and 1.51% respectively.

The increase in public health care boosts the health of unskilled labour (and hence its participation rate) by 9.94%. This is relatively more than the improvement of 8.08% in the health of skilled labour. Unskilled labour's health is affected only by changes in public health care whereas skilled labour's health is affected by changes in both public and private health care provision (Table 1).

Table 1 Changes in health, experiment 1 (%)

Type of labour	β =0	β=0.5	β=1	β=2
Skilled labour	8.073	8.192	8.309	8.534
Unskilled labour	9.939	9.995	10.050	10.158

As the health elasticity, β, is increased, the improved health of workers feeds back into the labour market via improved labour market participation rates (Table 2). Again, unskilled labour is able to benefit slightly more.

Table 2 Changes in labour market participation rates, experiment 1 (%)

Type of labour	β =0	β=0.5	β=1	β=2
Skilled labour	0	0.429	0.852	1.679
Unskilled labour	0	0.517	1.015	1.955

For β = 0, skilled labour gains and unskilled labour and capital lose from an expansion in (public) health care and contraction of non-health sectors. As β rises both skilled and unskilled labour are worse off (Table 3).

Table 3 Changes in factor rewards, experiment 1 (%)

Type of factor	β =0	β =0.5	β=1	β=2
Skilled labour	0.169	-0.010	-0.186	-0.531
Unskilled labour	-0.007	-0.256	-0.489	-0.912
Capital	-0.162	0.142	0.439	1.014

The changes in factor remuneration can be explained in terms of the changes in labour market participation rates. As the health elasticity goes up, an given increase in the level health leads to a higher labour market participation rate. Labour thus becomes relatively less scarce compared to capital, which is reflected in a fall in wages and a rise in rents.

At low levels of β, all households are relatively worse off, except for childless working households who benefit from the rise in skilled wages (Table 4 and 5). As β rises, working households' utility eventually improves as these households benefit from increased labour market participation. As β is increased, production in all sectors eventually rises. This boosts government tax revenues up to 0.95% for β=2 and mitigates the fall in transfers to all households (transfers fall by 2.27% for β =2). Consequently, non-working households are relatively less worse off as β rises. The improved welfare of working households (who benefit directly from increased participation in the labour market), combined with smaller reductions in the welfare of non-working households (for whom the fall in government transfers is less pronounced) and increases in government consumption of health and non-health goods, can lead to an overall welfare gain of up to 10.091 billion pounds (a relative change of 1.07%).

Table 4 Equivalent variations, experiment 1 (billions £)

Type of household	β=0	β=0.5	β=1	β=2
Pensioners	-3.298	-2.487	-1.694	-0.160
Non-working, children	-0.611	-0.515	-0.422	-0.240
Non-working, no children	-0.670	-0.508	-0.350	-0.043
Working, children	-1.316	-0.569	0.163	1.577
Working, no children	0.015	0.852	1.672	3.255
Overall (incl. government consumption of public goods)	**-0.610**	**2.153**	**4.860**	**10.091**

Table 5 Equivalent variations, experiment 1 (% of original income)

Type of household	β=0	β =0.5	β=1	β=2
Pensioners	-1.860	-1.403	-0.955	-0.090
Non-working, children	-4.327	-3.649	-2.985	-1.702
Non-working, no children	-1.914	-1.451	-0.998	-0.122
Working, children	-0.571	-0.247	0.071	0.684
Working, no children	0.005	0.273	0.536	1.043
Overall (incl. government consumption of public goods)	**-0.064**	**0.227**	**0.513**	**1.066**

Experiment 2: A 10% rise in the price of pharmaceuticals – government budget fixed in value

Government expenditures on health care, including all pharmaceutical imports, are fixed in value (foreign exchange) terms such that a rise in the price of health care lowers the quantity of health care provision. Similarly, a rise in the price of pharmaceutical imports is matched by and increase in foreign exchange needed to pay for these imports, such that pharmaceutical imports are constant. The model returns values for the domestic price (rises by 18.6%) and the import price (increases by 2.07%), which agree with the targeted increase in the price of the pharmaceutical composite of 10%.[24]

Following the pharmaceutical price rise resources move into the production of pharmaceuticals (grows by 1.4%) and consumption falls (by approximately 9.4%). Imports of pharmaceuticals are constant by design such that exports contract by approximately 19.5%. Confronted with higher unit costs of intermediate inputs, public and private health care increase their prices by approximately 0.86%. The rise in the price of health care leads to a drop in demand for private health care and a fall in the production of public health care (NHS and private health care contract by 0.85% and 1.01% respectively). Production, consumption imports and exports and prices of other sectors remain fairly constant. All factors of production experience a fall in relative rewards of less than 0.26% for all values of the health elasticity.

As predicted, the government consumes and provides less health care (a fall of approximately 0.85%) and increases production of other goods (other services and public administration and defence increase by less than 0.2%). Lower levels of public and private health care imply a fall in the level of health for skilled and unskilled labour. On average health deteriorates by 0.86%, but the change is slightly more pronounced for skilled labour as they consume both public and private health care, and the latter contracts relatively more. Consequently, labour market participation rates fall a for positive health elasticity (again by more for skilled labour).

Government income from taxes falls by 0.11%. In order to keep its finances balanced the government reduces transfers to households by 0.28%. Household welfare diminishes by a fairly small percentage for working households (<0.25% across all levels of β), but by relatively more for non-working households who are solely reliant on income from government transfers. This implies that the loss in wage income is relatively less than the loss in income from transfers such that households who receive income from both sources are less worse off than households living from state benefits only. Overall welfare (a composite of household expenditure on consumption and savings, and government consumption) deteriorates by around 0.973 billion pounds.

[24] We obtain a 10% increase in the market price of pharmaceuticals by postulating that the price change is driven by an increase in the exogenous world import price of pharmaceuticals, which then generates the mentioned changes in import and domestic pharmaceutical prices.

The results are relatively robust to changes in the elasticity of labour market participation with respect to health (β). The effect of changing the health elasticity is illustrated below for a selection of variables.

Table 6 Change in labour market participation rates: experiment 2 (%)

Type of labour	β=0	β =0.5	β =1	β =2
Skilled labour	0	-0.05	-0.101	-0.210
Unskilled labour	0	-0.048	-0.097	-0.198

Table 7 Changes in health: experiment 2 (%)

Type of labour	β=0	β =0.5	β=1	β =2
Skilled labour	-0.879	-0.892	-0.904	-0.931
Unskilled labour	-0.853	-0.859	-0.865	-0.878

Table 8 Changes in factor rewards: experiment 2 (%)

Type of factor	β=0	β =0.5	β=1	β =2
Skilled labour	-0.145	-0.123	-0.1	-0.051
Unskilled labour	-0.144	-0.125	-0.107	-0.070
Capital	-0.115	-0.149	-0.183	-0.256

For a given fall in the level of health, a higher β exacerbates the fall in labour market participation rates (Table 6). A lower labour market participation rate decreases effective labour supply to all sectors in the economy, including health care, thereby reinforcing the negative health effect of lower levels of health care. As a consequence, the fall in health of workers is more pronounced (Table 7). Also, given the demand for factors of production, the more pronounced fall in effective labour supply for higher values of the health elasticity implies that relative to capital, labour becomes relatively scarce. This reinforces the fall in rents on capital and mitigates the fall in wages (Table 8). Finally, a higher elasticity of labour market participation to health increases the loss in household welfare as measured by the equivalent variation (Table 9). Relative to original income non-working households are still worse off than working households due to the fall in income transfers as β rises (Table 10).

Table 9 Equivalent variations: experiment 2 (billions £)

Type of household	β=0	β =0.5	β=1	β=2
Pensioners	-0.202	-0.292	-0.384	-0.577
Non-working, children	-0.028	-0.038	-0.049	-0.072
Non-working, no children	-0.040	-0.058	-0.076	-0.115
Working, children	-0.185	-0.267	-0.352	-0.531
Working, no children	-0.214	-0.306	-0.402	-0.602
Overall (incl. government consumption of public goods)	**-0.973**	**-1.279**	**-1.594**	**-2.255**

Table 10 Equivalent variations: experiment 2 (% of original income)

Type of household	β=0	β =0.5	β=1	β=2
Pensioners	-0.114	-0.164	-0.217	-0.326
Non-working, children	-0.196	-0.271	-0.348	-0.509
Non-working, no children	-0.114	-0.166	-0.218	-0.329
Working, children	-0.080	-0.116	-0.153	-0.230
Working, no children	-0.068	-0.098	-0.129	-0.193
Overall (incl. government consumption of public goods)	**-0.103**	**-0.135**	**-0.168**	**-0.238**

Experiment 3: A 10% rise in the price of pharmaceuticals – level of public health care fixed

In addition to experiment 2, the government increases its expenditure on NHS care in order to maintain the number of people that are receiving treatment under the NHS. From the previous experiment we know that the price of public health care increases by approximately 0.86% following a 10% rise in the price of pharmaceuticals. Hence, in order to maintain previous levels of public health care the government should match the price increase of health care by an identical increase in expenditures on public health care of 0.86%. As this is such a minor change, results differ only marginally and a short summary of the differences is given below.

Pharmaceutical production goes up by 0.47% extra as more intermediate inputs from the pharmaceutical industry are needed to produce the additional public health care. For identical reasons, production of medical, precision and optical instruments expands by 0.19% (compared to 0.04% in experiment 2). By assumption, the level of public health care remains constant, such that private health care contracts by 1.09%, 0.08% more than in experiment 2. A distinctive result is that the health of unskilled labour, which depends solely on levels of NHS provisioning, is maintained at its original level. Therefore, unskilled labour participates at the same rate as before and supplies the same amount of labour. Skilled labour is worse off in terms of health by 0.18% (though better off than in experiment 2) and in terms of labour market participation (falls in range of 0.01% to 0.04% for positive health elasticity). In order to maintain levels of public health care following an increase in the cost of provisioning, the government must reduce transfer payments to households, given that expenditures on other goods are still fixed in value. Consequently, compared to experiment 2 all households are worse off for low levels of β. As β rises, working households are better off relative to experiment 2 because of improved health and higher labour market participation. In line with these patterns, overall welfare falls by -1.029 and -1.233 billion pounds for $\beta = 0$ and $\beta = 2$ respectively (the former decrease is higher and the latter decrease is lower compared to experiment 2).

7. Conclusions and comments

This paper presents the results from a preliminary CGE assessment of health care in the United Kingdom. The paper models health provision and its effects on effective labour supply, and shows the magnitude of changes to factor rewards, health and labour market participation, and welfare that could be expected from scenarios of increased public health expenditure and increases in pharmaceutical prices.

The main findings of the paper are that increased public health expenditure improves health and leads to higher labour participation for both skilled and unskilled labour. These results depend on the effectiveness of health care, as represented in the model by an elasticity governing how labour participation rates respond to health provision. A fairly low rate of effectiveness is enough to ensure a welfare gain from increased public health provision.

Increased pharmaceutical prices have the opposite effect of reducing public and private health care provisioning due to a rise in the costs of inputs. Health deteriorates and – allowing labour supply changes conditioned on health – labour market participation falls. When the government increases public health care expenditures so as to maintain previous treatment levels, negative health and welfare effects are mitigated. Finally, health care provision has a differential impact across labour types, household types and indeed across time. Skilled labour is worse off in terms of employment relative to unskilled labour as private health care, consumed only by skilled labour only, becomes more costly and less available. Households with working members gain from an expansion in health care provided via the NHS as they benefit from improved labour market participation of their working members, whereas non-working households, who are dependent of state transfers, are worse off. Although in the short term expansion of health provision implies an immediate cost to society, in the longer term, when health effects materialise, this picture is altered as a higher effective labour force, increases domestic production, the tax earning ability of the government and thus increases income of working households *and* non-working households and overall welfare, depending on the effectiveness of health care in improving the health of the working population.

We modelled the positive gains from health provision that occur through increased effective labour supply. The model does not include effects that health care may have through increasing leisure time, or more general non-pecuniary benefits from increased health (see for example Clark and Oswald, 2002 on the contribution of health to happiness). Future research might include modelling such benefits, and might also improve on the manner in which health is incorporated into the model by incorporating explicit dynamics, including the modelling of generational changes (also touches upon the issue of ageing and sustainability of pension schemes), the manner in which ill individuals move to good health, and intra-household distribution of health benefits to individuals and workers. The CGE model currently does not separate different age groups (young, working age, old) and employed from unemployed, nor is there a difference between part-time and full-time work. In order to model how individuals move through the health system and how this affects participation in the labour market, economic growth and welfare it is crucial to get the numbers of persons and their demographic, socio-economic and employment characteristics right. Although the model distinguishes between rationed public health care and private care, each with a different clientele, we would also like to incorporate different types of care. Primary and secondary (medical and surgical) care typically have differential impact upon illness rates, health and effective labour supply and the inclusion of such variety in treatments may allow us to infer conclusions about cost effectiveness. Possibly the greatest obstacle of modelling the economic impact of changes in health and health provisioning is the availability of data. Refining the empirical basis of the model will be a crucial element of any progress made in the area of health modelling in a macroeconomic context.

References

Arndt, C. (2003), 'HIV/AIDS, Human Capital, and Economic Growth Prospects for Mozambique', Africa Region Working Paper Series, No. 48, The World Bank.

Arndt, C. and J.D. Lewis (2000), 'The Macro Implications of HIV/AIDS in South Africa: A Preliminary Assessment', *South African Journal of Economics*, Vol. 68, No. 5, pp. 856-887.

Arndt, C. and J.D. Lewis (2001), 'The HIV/AIDS Pandemic in South Africa: Sectoral Impacts and Unemployment', *Journal of International Development*, Vol. 13, No. 4, pp. 427-449.

Arndt, C. and P. Wobst (2002), 'HIV/AIDS and Labor Markets in Tanzania', *Trade and Macroeconomics Division Discussion Paper*, No. 102, IFPRI, Washington D.C.

Beghin J., B. Bowland, S. Dessus, D. Roland-Holst, and D. van der Mensbrugghe (1999) 'Trade, Environment, and Public Health in Chile. Evidence from an Economywide Model', *in* P. Fredriksson (ed.), *Trade, Global Policy and the Environment*. World Bank Discussion Paper 402, The World Bank, pp. 35-54.

Bruvoll, A., S. Glomsrod, H. Vennemo (1999), 'Environmental Drag: Evidence from Norway', *Ecological Economics*, Vol. 30, No. 2, pp. 235-249.

Canton, E. and E. Westerhout (1999a), 'A Model for the Dutch Pharmaceutical Market', *Health Economics*, Vol. 8, No. 5, pp. 391-402.

Canton, E. and E. Westerhout (1999b), 'Modelling the Dutch Pharmaceutical Market', *CPB Report*, No. 99/2, pp. 30-35.

Chatterji, M. and J.H.P. Paelinck (1991), 'A General Equilibrium Model of Health Care', *in* G. Duru and J.H.P. Paelinck (eds.), *Econometrics of Health Care*, pp. 237-248.

Clark, A.E. and A.J. Oswald (2002), 'A Simple Statistical Method for Measuring how Life Events affect Happiness', *International Journal of Epidemiology*, Vol. 31, pp. 1139-44.

DOH (2000), *Departmental Investment Srategy, November 2000*, UK Department of Health.

Folmer, K., J. Stevens, F. Van Tulder and E. Westerhout (1997), 'Towards an Economic Model of the Dutch Health Care Sector', *Health Economics*, Vol. 6, No. 4, pp. 351-363.

Garbaccio, R.F., M.S. Ho and D.W. Jorgenson (2000), *The Health Benefits of Controlling Carbon Emissions in China*, Kennedy School of Government, Harvard University, Cambridge, MA.

Garibaldi, P. (1998), 'Job Flow Dynamics and Firing Restrictions', *European Economic Review*, Vol. 42, pp. 245-75.

Kambou, G., S. Devarajan and M. Over (1992), 'The Economic Impact of AIDS in an African Country: Simulations with a General Equilibrium Model of Cameroon.' *Journal of African Economies*, Vol. 1, No. 1, pp. 103-130.

Kouwenaar, A. (1986), *A Basic Needs Policy Model: A General Equilibrium Analysis with Special Reference to Ecuador*, Ph.D. thesis, Erasmus Universiteit Rotterdam.

Li, J. C-I. (2002), ‘Including the Feedback of Local Health Improvement in Assessing Costs and Benefits of GHG Reduction’, *Review of Urban and Regional Development Studies*, Vol. 14, No. 3, pp. 282-304.

Martin, J.P. (1976), ‘Variable Factor Supplies and the Heckscher-Ohlin-Samuelson Model’, *Economic Journal*, Vol. 86, pp. 820-31.

Martin, J.P. and P.J. Neary (1980), ‘Variable Labour Supply and the Pure Theory of International Trade: An Empirical Note’, *Journal of International Economics*, Vol. 10, pp. 549-59.

ONS(2002), *Annual Abstract of Statistics 2002 Edition*, No. 138, The Stationary Office.

Rybczynski, T.M. (1955), ‘Factor Endowments and Relative Commodity Prices’, *Economica*, vol. 11, pp. 336-41.

Savard, L. and É. Adjovi (1997), ‘Adjustment, Liberalization and Welfare in Presence of Health and Education Externalities: a CGE applied to Benin’, *Cahier 97-07 du Centre de Recherche en Economie et Finance Appliquées*, CREFA, Département d'Economique, Faculté des Sciences Sociales.

van der Hoeven, R. (1987), *Planning for Basic Needs: A Basic Needs Simulation Model applied to Kenya*, Ph.D. thesis Vrije Universiteit Amsterdam, Amsterdam: Free University Press.

van der Hoeven, R. (1988), *Planning for Basic Needs: A Soft Option or a Solid Policy? A Basic Needs Simulation Model Applied to Kenya*, Aldershot: Gower.

Vennemo, H. (1997), ‘A Dynamic Applied General Equilibrium Model with Environmental Feedbacks’, *Economic modelling*, Vol. 14, No. 1, pp. 99-154.

Vianen, J.G. and J.G. Waardenburg (1975), ‘Integration of Health Care into a Multi-sector Model: with a Quantification for Tanzania’, *Discussion Paper Centre for Development Planning*, Erasmus University Rotterdam.